Marine Fisheries REVIEW

Vol. 54, No. 2
1992

National Oceanic and Atmospheric Administration • National Marine Fisheries Service

Spinner dolphin

Marine Fisheries REVIEW

On the cover: Spinner dolphin, *Stenella longirostris*. NMFS photo.

Articles *54(2), 1992*

The *Marine Fisheries Review* (ISSN 0090-1830) is published quarterly by the Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA 98115. Annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402: Annual subscription $7.00 domestic, $8.75 foreign. For new subscriptions write: New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

Publication of material from sources outside the NMFS is not an endorsement and the NMFS is not responsible for the accuracy of facts, views, or opinions of the sources. The Secretary of Commerce has determined that the publication of this periodical is necessary for the transaction of public business required by law of this Department. Use of the funds for printing this periodical has been approved by the Director of the Office of Management and Budget.

The NMFS does not approve, recommend, or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to NMFS, or to this publication furnished by NMFS, in any advertising or sales promotion which would indicate or imply that NMFS approves, recommends, or endorses any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this NMFS publication. Second class postage is paid in Seattle, Wash., and additional offices.

POSTMASTER: Send address changes for subscriptions for this journal to—*Marine Fisheries Review*, c/o Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Lethal Parasites in Oysters from Coastal Georgia with Discussion of Disease and Management Implications

EARL J. LEWIS, FREDERICK G. KERN, AARON ROSENFIELD,
STUART A. STEVENS, RANDAL L. WALKER, and PETER B. HEFFERNAN

Introduction

Oysters in many parts of the world have declined in abundance since the 19th century, probably in large part from indiscriminate harvesting and destruction of beds (Sindermann, 1970). Lyles (1969) published data showing a similar decline in the U.S. commercial harvest of oysters, *Crassostrea virginica*, in this century. During the last several decades, an increasing awareness of the role shellfish pathogens play in the population dynamics of oysters has been reflected in publications of Sindermann and Rosenfield (1967), Sindermann (1970, 1990), Kinne (1983), Farley et al. (1988), Fisher (1988), and Farley (1989, In press). Disease is clearly a major factor affecting the abundance of shellfish stocks. Malpeque Bay disease (Needler and Logie, 1947) and other distinct diseases caused by the parasites *Perkinsus marinus* (Mackin et al., 1950; Levine, 1978), *Haplosporidium nelsoni* (Haskin et al., 1966; Sprague, 1978), and *H. costale* (Wood and Andrews, 1962) have been reported to cause mortalities in the oyster, *C. virginica* (Sindermann, 1990; Farley, In press).

Earl J. Lewis, Frederick G. Kern, and Aaron Rosenfield are with the Oxford Cooperative Laboratory, Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 904 South Morris Street, Oxford, MD 21654. Stuart A. Stevens is with the Coastal Resources Division, Georgia Department of Natural Resources, 1 Conservation Way, Brunswick, GA 31523. Randal L. Walker and Peter B. Heffernan are with the University of Georgia's Marine Extension Service, Shellfish Research Laboratory, P.O. Box 13687, Savannah, GA 31416.

ABSTRACT— Extensive mortalities of oysters, Crassostrea virginica, *occurred from 1985 through 1987 in coastal waters of Georgia. Fluid thioglycolate cultures of oysters collected from 16 of 17 locations revealed infections by the apicomplexan parasite* Perkinsus marinus. *An ascetosporan parasite,* Haplosporidium nelsoni, *was also observed in histopathological examination of oysters from 4 of the locations. While the range of* H. nelsoni *currently is recognized as the east coast of the United States from Maine to Florida, this is the first report of the parasite in Georgia waters. This paper documents the occurrence of these two lethal parasites in oysters from coastal waters of Georgia, along with potential disease and management implications. Results of an earlier independent and previously unpublished survey are also discussed which document the presence of* P. marinus *in Georgia as early as 1966.*

In 1966 and 1968, one of the authors (Rosenfield) made a histological study of oysters from coastal Georgia, as part of an Atlantic coastal survey to determine the status of oyster disease agents and parasites. At that time, *H. nelsoni* was causing mortalities of oysters from Delaware and Chesapeake Bays, and *P. marinus* was causing serious losses to oysters in the Gulf of Mexico region. Results of this study (unpubl.) document the occurrence of *P. marinus* in Georgia waters as early as 1966; however, *H. nelsoni* was not observed at that time.

In November 1985, the Georgia Department of Natural Resources (DNR) began receiving complaints from the shellfish industry of widespread mortalities of oysters, *C. virginica*, from commercial leases. Initial mortalities were attributed to natural causes, alarming neither industry nor the DNR. However, as additional shellfishermen began to report increased mortalities, the DNR initiated field surveillance at selected areas. Results of the survey showed that where mortalities occurred they ranged from 40 to 100 percent. Most locations exhibited mortalities of 60-70 percent.

To determine the cause of mortalities, NOAA's National Marine Fisheries Service (NMFS) and the Georgia DNR began a cooperative study in January of 1986. Data in this report suggest that epizootic levels of infection with *P. marinus* ("Dermo") are the most probable causes of the mortalities. The report also documents the occurrence of *H. nelsoni* ("MSX") in the coastal waters of Georgia for the first time.

Methodology

Samples of apparently healthy oysters were collected for histological examination from 17 sites throughout coastal Georgia during two studies (Fig. 1). The same protocols were followed for both studies, with the exception of the number of oysters examined, and quantifying the disease intensity of the earlier unpublished work by Rosenfield.

In January 1966, samples of 25 oysters each were collected from Wassaw Creek and the Duplin and Woodbine Rivers, and processed for histological examination. Subsequently, 15-20 animals were collected and processed for a follow-up evaluation in April of 1968 from each of the following four sites: Eagle Creek and the Darien, Wilmington, and Brickhill Rivers. Intensities of infection were not recorded.

Beginning in January of 1986, oysters were collected from Mud Creek

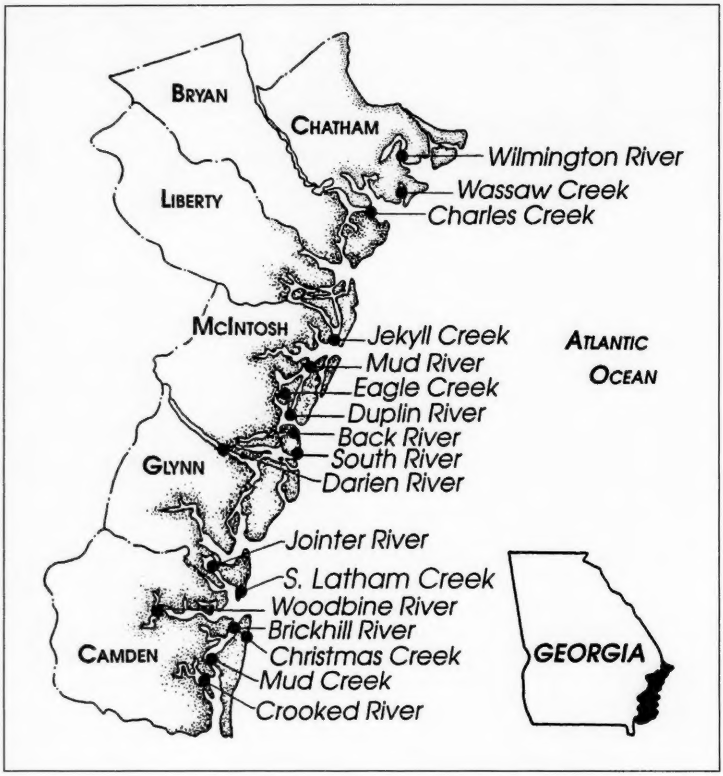

Figure 1.—Distribution of sample sites in coastal Georgia (1966-87).

and Crooked River. During November 1986, oysters were collected from Jekyll, South Latham, and Charles Creeks, and the Jointer River. In November 1987, oysters were gathered from Christmas Creek, as well as Back, Mud, and South Rivers. One hundred oysters were collected at each site, of which 50 were selected randomly and processed for histological examination.

In each study, collections were made by personnel of the Georgia DNR and sent to the NMFS Laboratory at Oxford, Md., for processing and detection of the epizootic agent(s). DNR personnel also provided salinity and temperature data for 1986-87.

Animals were macroscopically examined and processed for histology using standard Oxford Laboratory histological techniques (Howard and Smith, 1983). Each oyster was measured, examined visually for gross abnormalities, and assigned a condition based on a scale of 1 (very watery) to 9 (very fat), as explained in Table 1. Fluid thioglycolate cultures of oyster rectal tissue (Ray, 1966) were made to diagnose *P. marinus* infection.

Light microscopy was used to determine the presence and intensity of infections in individual animals. In the 1986-87 study, infections were assigned numerical values of intensity from 1 to 9, as indicated in Table 2.

Results of the thioglycolate cultures and histopathology were used to determine disease intensities of *P. marinus* and *H. nelsoni* in each of the sample populations. This value is calculated by the summation of disease intensity in all animals from a site, divided by the number of animals tested for that site (Ray, 1954).

Table 1.—Field survey and macroscopic oyster examination data, 1986-87 survey.

Sample area	Salinity ‰	Water temp. (°C)	Mean length (mm)	Condition range[1]	Mean condition[1]
Jan. 1986					
Mud Creek	28[2]	13.0	89.4	1-4	3.0
Crooked R.	28[2]	13.0	86.4	1-5	2.1
Mean	28	13.0	87.9	1-5	2.6
Nov. 1986					
Jointer R.	32	23.0	68.4	4-6	4.9
S. Latham Cr.	31	23.0	65.0	2-5	4.1
Jekyll Cr.	29	22.0	52.8	2-6	4.5
Charles Cr.	32	22.0	53.1	2-6	3.5
Mean	31	22.5	59.8	2-6	4.3
Nov. 1987					
Christmas Cr.	30	16.0	78.4	2-6	4.6
Mud R.	30	16.5	92.4	1-5	2.5
Back R.	32[2]	18.8[2]	88.0	1-5	3.6
South R.	32[2]	18.8[2]	72.0	2-6	4.1
Mean	31	17.5	82.7	1-6	3.7

[1]Criteria for condition based on visual observations and rated on a scale of 1-9 as follows: 1 = watery(-), 2 = watery, 3 = watery(+), 4 = medium(-), 5 = medium, 6 = medium(+), 7 = fat(-), 8 = fat and 9 = fat(+).
[2]Estimated values based on information of the area. This portion of data for sample was destroyed in shipment.

Table 2.—Prevalence and intensity of oyster parasites *Perkinsus marinus* and *Haplosporidium nelsoni* in coastal waters of Georgia.

Sample area and survey date	*P. marinus*[1]			*H. nelsoni*[2]		
	n	Percent prevalence	Sample population intensity[3]	*n*	Percent prevalence	Sample population intensity[3]
Jan. 1966						
Woodbine R.	25	12	NA[4]	25	0	NA
Wassaw Cr.	25	12	NA	25	0	NA
Duplin R.	25	44	NA	25	0	NA
Mean	25	23		25	0	
April 1968						
Darien R.	10	10	NA	20	0	NA
Eagle Cr.	10	10	NA	15	0	NA
Wilmington R.	15	0	NA	15	0	NA
Brickhill R.	10	10	NA	20	0	NA
Mean	11	8		18	0	
Jan. 1986						
Mud Cr.	25	100	NA	50	6	0.4
Crooked R.	25	100	3.6	50	0	0.0
Mean	25	100	3.6	50	3	0.2
Nov. 1986						
Jointer R.	22	88	3.6	50	0	0.0
S. Latham Cr.	25	100	3.9	50	6	0.3
Jekyll Cr.	25	96	3.4	50	0	0.0
Charles Cr.	25	100	3.8	50	0	0.0
Mean	24	96	3.7	50	2	0.1
Nov. 1987						
Christmas Cr.	25	100	4.9	50	2	0.1
Mud R.	25	100	4.2	50	0	0.0
Back R.	25	100	3.8	50	0	0.0
South R.	25	100	4.1	50	2	0.2
Mean	25	100	4.3	50	1	0.03

[1]*P. marinus* results based on thioglycolate cultures of rectal tissue.
[2]*H. nelsoni* results based on histological observations.
[3]Criteria for intensity data based on a numerical scale from 1 to 9: 1 = very light, 3 = light, 5 = moderate, 7 = heavy, 9 = very heavy.
[4]NA = Data not available.

Results

During 1986-87, oysters were obtained from high salinity waters, between 28 and 32‰, with temperatures of 13°-23°C. Oysters ranged in length from 25 to 143 mm, and their mean visually assessed condition varied from watery(–), or very poor, to medium(+) (Table 1). No fat oysters were found in any of the samples. Similar data were not available from 1966 or 1968 samples.

Thioglycolate cultures and histopathological examination of oysters revealed the presence of *P. marinus* from 16 of the 17 sites sampled, and *H. nelsoni* in oysters from 4 sites (Table 2). Parasites were found in oysters throughout coastal Georgia, without indication of a regional distribution.

Oysters collected from Georgia in 1966 and 1968 revealed the presence of *P. marinus* in 0-44% of the oysters examined. *Perkinsus marinus* was observed in 12-44% of oysters sampled in January of 1966, but no mortalities were reported. Two years later, *P. marinus* was found in 0-10% of the oysters examined, again with no reports of associated mortalities. Examination of oysters in 1986-87 revealed *P. marinus* occurred at all sites sampled. Prevalence of the disease ranged from 88 to 100%, with intensities of infection ranging from very light (1) to very heavy (9). Infections showed an increase in sample population intensity from a mean of 3.6 in January 1986 to 4.3 in November 1987. Mean intensity of infection for the entire study was 3.9.

Haplosporidium nelsoni was not observed in either of the 1966 or 1968 samples; however, the parasite was diagnosed in a total of eight animals from four sites during 1986 and 1987. Prevalence of *H. nelsoni* from these sites ranged from 2 to 6%, with sample population intensities ranging from 0.1 to 0.4. Intensity of disease among individual infected animals varied from very light (1.0) to heavy (7.0).

Discussion

Since the turn of the century, annual U.S. oyster production has fallen from about 158 million pounds of meats (Lyles, 1969) to 29.9 million pounds of meats in 1989 (USDOC, 1990). While overharvesting, predation, and deteriorating water quality are believed to be responsible for much of the decline (Leonard et al., 1989), diseases have also been a significant factor.

Traditionally, Chesapeake Bay led the United States in oyster production prior to *H. nelsoni* and *P. marinus* becoming endemic to the area (Anderson and Power, 1957). Following several decades of severe losses due to oyster diseases, there has been a complete reversal in oyster production in the nation. Chesapeake Bay now contributes only 14 percent of the annual U.S. oyster harvest, compared to 50 percent produced in the Gulf of Mexico region, principally by Louisiana (USDOC, 1990). Commensurate with this change, oyster imports since 1986 have consistently exceeded the U.S. commercial landings (USDOC, 1990), to meet the American consumer demand.

Perkinsus marinus, first described in oysters from the Gulf of Mexico by Mackin et al. (1950), causes a chronic disease which can be fatal in *C. virginica* (Mackin, 1951). Some confusion apparently exists regarding the parasite's northern range and its presence in coastal bays of Maryland and Virginia. Quick (1977) reported its range from Massachusetts south into the Gulf of Mexico. Kern et al. (1973) also reported the parasite to occur in *C. virginica* growing in Hawaii. However, later publications (Andrews, 1988; Sindermann, 1990) cite Delaware Bay as the northern boundary. In an unpublished report, Farley and Plutschak[1] observed possible, very early infections of *P. marinus* in 8% of oysters diagnosed by rectal thioglycolate cultures from three sites in Massachusetts. This suggests that oysters in waters as far north as Massachusetts may indeed experience *P. marinus* infections, as earlier publications suggested. The most serious effects of *P. marinus* infections, however, occur in the Gulf of Mexico, where mortalities are estimated at 50% or more annually (Craig et al., 1989). The occurrence of *P. marinus* in oysters north of Delaware Bay apparently remains a rare event at this time. Andrews (1988) claimed that seaside bays of the eastern shore of Virginia, and usually Maryland, were free of *P. marinus*. Lewis and Kern (independent personal observations) found the parasite in oysters from Maryland and Virginia portions of Chincoteague Bay. Prevalences as high as 96% were observed, of which 76% were judged to be heavy or very heavy infections. Associated mortalities of up to 84% were reported as being caused primarily by *P. marinus*.

In Georgia, *P. marinus* was found as early as 1966 when it was observed in oysters from Wassaw Creek and the Duplin and Woodbine Rivers. With the exception of oysters from the Duplin River (44%), the prevalence of infection from *P. marinus* never exceeded 12% in the 1966-68 survey. Any mortality which might have occurred as a result of *P. marinus* infections at these low prevalences would likely have been masked by what are considered normal losses to natural causes, and thus never reported.

Perkinsus marinus is, however, considered to be the etiological agent responsible for Georgia oyster mortalities observed in 1985-87, because of its high prevalence and intensity in thioglycolate cultures and histological sections of the oysters examined. Sampling in 1986 and 1987 showed continued high prevalence of *P. marinus* infections, with a slight but progressive increase in intensities.

Disease prevalence and intensity of *P. marinus* reflect seasonal parasite activity which strongly correlate with water temperature (Quick and Mackin, 1971). Infections are most severe during summer and early fall, then decrease in intensity as water temperatures drop. Results of this study failed to demonstrate statistically any correlation between water temperature and disease intensity. This is attributed to a lack of seasonal data and does not dispute the existence of the relationship. However, the trend of our disease in-

[1]C. A. Farley, National Marine Fisheries Service, NOAA, Northeast Fisheries Science Center, Oxford, MD 21654, and D. L. Plutschak, Maryland Department of Natural Resources, Oxford, MD 21654. Personal commun.

tensity data graphically resembles that of Quick and Mackin (1971) for Florida oysters infected by *P. marinus* at comparable temperatures.

Gross condition observed in 1986-87 reflects a lack of stored glycogen or "fatness." Low gross conditions are typical of oysters stressed by high water temperature, disease, spawning, and other events causing an animal to expend disproportionate amounts of energy on self maintenance. This results in depletion of glycogen reserves which translates into a poor condition. At the time of the year samples were taken, oysters would be expected to have a condition above medium (5). In all cases, the mean condition was below 5 and no oysters above a value of 6 were observed.

Oyster mortalities were first reported from Camden County, Ga., early in November 1985, and subsequently from McIntosh County in the beginning of January 1986. Reports occurred at a time when water temperatures were abnormally high and following a period of extensive rainfall associated with several tropical storms and hurricanes.

Typically, the intensity of *P. marinus* infections seen in the surviving oysters sampled in January 1986 would not be considered sufficient in itself to cause the extensive mortalities experienced in November 1985. However, by the time samples were taken the most heavily infected oysters had died. Quick and Mackin (1971) reported mortality in Florida oysters infected by *P. marinus* to begin at a medium infection intensity under normal circumstances. That would approximate a moderate infection intensity, or stage 5, in the current study. While infection intensity of individual oysters exceeded a stage 5, sample population intensity for sites ranged from 3.4 to 4.9. The added stress of extended periods of abnormally high water temperatures and unusually heavy rainfall are considered contributing factors to the mortalities. The same pressures likely continued during 1986, as climatic conditions were reported to have mirrored those of 1985 (Stevens, Personal commun.).

Since *H. nelsoni* was established as the causative agent of the Delaware Bay oyster epizootic (Haskin et. al., 1966), cyclic periods of oyster mortalities caused by *H. nelsoni* have continued to occur along the Atlantic coast in Massachusetts, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and, to a limited extent, North Carolina (Haskin and Andrews, 1988). With the exception of New Hampshire and Rhode Island, *H. nelsoni* has been observed in oysters from each state along the east coast from Maine to Florida (Haskin and Andrews, 1988; Sindermann, 1990). To date, however, parasite-induced mortalities have not been reported from Maine or states south of North Carolina.

The most severe effects of *H. nelsoni* are seen in Delaware and Chesapeake Bays (Haskin et. al., 1965; Andrews and Wood, 1967; Farley, 1975; Lewis, 1988). As a direct result of *H. nelsoni* infections, oyster production in Delaware Bay dropped from about 8 million pounds of meats in 1953 to 167,000 pounds by 1960 (Sindermann and Rosenfield, 1967). Likewise, oyster production in Chesapeake Bay fell from 39.2 million pounds of oyster meats in 1955 (Anderson and Power, 1957) to less than 4.1 million pounds of meats in 1989 (USDOC, 1990). Disease caused by *Perkinsus marinus* and *H. nelsoni* has had a combined effect in reducing oyster production from Chesapeake Bay.

In January 1986, *H. nelsoni* was detected for the first time in Georgia in three oysters from Mud Creek. Although very heavy levels of intensity were observed in a few oysters (7.0), *H. nelsoni* is not believed to be the principal agent responsible for mortalities, because of its low prevalence and intensity in the sample population (0.0-0.4). Examination of the November 1986 and 1987 samples also revealed the presence of *H. nelsoni* in oysters from three additional locations in coastal Georgia.

Management Implications

Minimizing the effect of disease caused by *P. marinus* involves several key strategies which include: 1) Avoiding the transplantation of diseased seed stock, 2) reducing the time oysters are exposed to the disease (this may involve reducing the legal harvest size of oysters, and planting seed in the fall and winter after the disease process has been slowed by decreased water temperatures), and 3) isolating grow-out areas from known diseased areas (Andrews and Ray, 1988).

The cross-infection of oysters by *P. marinus* from other mollusks is a management concern with regard to the isolation of shellfish beds from infectious sources. Ray (1954), Andrews (1955), Andrews and Hewatt (1957), Perkins (1988), and McGladdery et. al. (1991) reported observations of *Perkinsus* and *Perkinsus*-like organisms in many other mollusks along the east coast of the United States. Although their taxonomic identity has not always been established, the organisms are apparently ubiquitous and easily transmitted. Results of earlier, unsuccessful work to cross-infect mollusks with *Perkinsus* spp. isolated from other molluscan species led to belief in the host specificity of parasites. Goggins et al. (1989), however, demonstrated cross-infection of Australian *Perkinsus* spp. from 6 molluscan sources to 10 species of mollusks; they concluded they were dealing with at least 2 species of *Perkinsus* and low levels of host specificity. The potential for cross infection, along with the observation of another species of *Perkinsus* found in scallops on the east coast, may be a concern where oysters are not infected by *P. marinus*. McGladdery et al. (1991) recently described a new species, *Perkinsus karlssoni*, in the bay scallop, *Argopecten irradians*, which was observed in specimens from the Gulf of St. Lawrence and Atlantic Nova Scotia, Can., as well as Rhode Island, Connecticut, and Cape Cod, Mass., in the United States. Whether *P. karlssoni* or other *Perkinsus*-like organisms may cross-infect *C. virginica* is yet to be demonstrated.

Mortalities are increased in areas, such as the Chesapeake Bay, where high levels of both *P. marinus* and *H. nelsoni* coexist. In these situations, Andrews (1979) believes *H. nelsoni* outcompetes *P. marinus*. This information highlights a potential danger to

Georgia shellfisheries, considering the recent discovery of *H. nelsoni* in Georgia oysters.

Responding to scientific evidence that *H. nelsoni* is intolerant of salinities below 10‰ (Andrews, 1964; Ford, 1985; Ford and Haskin, 1988a), oyster management officials now emphasize the use of lower salinity growing areas to avoid, or at least minimize, the effects of *H. nelsoni* on oysters (Ford and Haskin, 1988b). Because the transplantation of seed and shell stock is a vital component of management, the introduction of infected animals into previously unaffected systems is of great concern (Rosenfield and Kern, 1987; Sindermann, In press). Mortalities, with long-lasting consequences, can be linked to the movement of shellfish stocks (Farley, In press). It is likely, to some degree, that the progressive spread of diseases within Chesapeake Bay may be linked to the movement of infected seed stock.

Another management strategy involves the development of disease-resistant stocks through selective breeding techniques (Haskin and Ford, 1979; Ford, 1987). While some success has been made along these lines with regard to *H. nelsoni*, several problems remain. First, under intense infection pressures, even resistant strains succumb to *H. nelsoni* (Ford and Haskin, 1988b). Second, disease resistance against *P. marinus* has not been achieved. It is unknown at this time if animals resistant to *H. nelsoni* are resistant to other fatal oyster disease agents. Although disease resistance is viewed as a valuable asset in mariculture operations, it is not readily applicable to a wild fishery. In other than strictly controlled mariculture operations, diminished resistance by interbreeding with wild shellfish stocks may likely result over time.

Management of *P. marinus* has been shown to be more complex in the Gulf of Mexico than in the Chesapeake Bay region, largely because of elevated southern water temperatures (Andrews and Ray, 1988). It also may be premature to assume that management strategies devised to deal with *H. nelsoni* in the northeastern United States will apply in Georgia; climate and marsh ecology of coastal Georgia contrast greatly with the remainder of the eastern United States. This is reflected in the biology of local shellfish (Walker and Humphrey, 1984; Walker and Tenore, 1984; Walker, 1985; Heffernan et al., 1989a,b). For example, distribution, growth rates, and reproductive patterns for Georgia oysters and hard clams, *Mercenaria mercenaria*, contrast greatly when compared with other areas of the Atlantic coastline. Georgia oysters have extended reproductive periods, while polymodal reproductive cycles occur in hard clams. In Georgia, oysters primarily occur intertidally and spawn from April to October (Harris, 1980; Heffernan et al., 1989b); whereas, in most of their distribution, oysters occur subtidally. It may be reasonable to expect differences in the ecology and dynamics of pathogens in coastal Georgia as compared with the northeastern United States. Based on the uniqueness of the Georgia habitat, studies are in progress to develop approaches that will reduce mortalities from the effects of *H. nelsoni* and *P. marinus*. These include allowing the earlier harvest of marketable oysters, prior to the onset of mortalities resulting from parasitic infections.

Acknowledgments

The work was supported in part by the Coastal Resources Division of the Georgia Department of Natural Resources and the Georgia Sea Grant Program under grant number NA84AA-D-00072. We thank C. Austin Farley, Shawn McLaughlin, and Carl Sindermann for critical review of the manuscript, and Jane Keller for technical editing.

Literature Cited

Anderson, A. W., and E. A. Power. 1957. Fishery statistics of the United States, 1955. U.S. Dep. Inter., Fish Wildl. Serv., Stat. Dig. 41, 446 p.

Andrews, J. D. 1955. Notes on fungus parasites of bivalve mollusks in Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 45:157-163.

————. 1964. Oyster mortality studies in Virginia. IV. MSX in James River public seed beds. Proc. Natl. Shellfish. Assoc. 53:65-84.

————. 1979. Oyster diseases in Chesapeake Bay. Mar. Fish. Rev. 41(1-2):45-53.

Andrews, J. D. 1988. Epizootiology of the disease caused by the oyster pathogen *Perkinsus marinus* and its effects on the oyster industry. *In* W. Fisher (Editor), Disease processes in marine bivalve molluscs, p. 47-63. Am. Fish. Soc., Spec. Publ. 18, Bethesda, Md.

———— and W. G. Hewatt. 1957. Oyster mortality studies in Virginia. II. The fungus disease caused by *Dermocystidium marinum* in oysters of Chesapeake Bay. Ecol. Monogr. 27:1-26.

———— and S. M. Ray. 1988. Management strategies to control the disease caused by *Perkinsus marinus*. *In* W. Fisher (Editor), Disease processes in marine bivalve molluscs, p. 257-264. Am. Fish. Soc., Spec. Publ. 18.

———— and J. L. Wood. 1967. Oyster mortality studies in Virginia. VI. History and distribution of *Minchinia nelsoni* (MSX), a pathogen of oysters, in Virginia. Chesapeake Sci. 8(1):1-13.

Craig, A., E. N. Powell, R. R. Fay, and J. M. Brooks. 1989. Distribution of *Perkinsus marinus* in Gulf coast oyster populations. Estuaries 12(2):82-91.

Farley, C. A. 1975. Epizootic and enzootic aspects of *Minchinia nelsoni* (Haplosporida) disease in Maryland oysters. J. Protozool. 22(3):418-427.

————. 1989. Selected aspects of neoplastic progression in mollusks. *In* H.E. Kaiser (Editor), Comparative aspects of tumor development, cancer growth and progression, p. 24-31. Kluwer Acad. Publ., Netherl.

————. In press. Mass mortalities and infectious lethal diseases in bivalve mollusks and associations with geographic transfers of populations. *In* A. Rosenfield and R. Mann (Editors), Dispersal of living organisms into aquatic ecosystems. Md. Sea Grant Coll. Publ., Univ. Md., Coll. Park.

————, P. H. Wolf, and R. A. Elston. 1988. A long-term study of "microcell" disease in oysters with a description of a new genus, *Mikrocytos* (g.n.) and two new species, *Mikrocytos mackini* (sp.n.) and *Mikrocytos roughleyi* (sp.n.). Fish. Bull. 86(3):581-593.

Fisher, W. (Editor). 1988. Disease processes in marine bivalve molluscs. Am. Fish. Soc., Spec. Publ. 18, 315 p.

Ford, S.E. 1985. Effects of salinity on survival of the MSX parasite *Haplosporidium nelsoni* (Haskin, Stauber, and Mackin) in oysters. J. Shellfish Res. 5(2):85-90.

————. 1987. Progress on the development of MSX-resistant oyster strains. *In* A. White (Editor), Shellfish diseases: Current concerns in the northeast, p. 12-14. Woods Hole Oceanogr. Inst., Tech. Rep. 87-13.

———— and H. H. Haskin. 1988a. Comparison of in vitro tolerance of the oyster parasite, *Haplosporidium nelsoni* (MSX) and hemocytes from the host, *Crassostrea virginica*. Comp. Biochem. Physiol. 90A(1):183-187.

———— and ————. 1988b. Management strategies for MSX (*Haplosporidium nelsoni*) disease in eastern oysters. *In* W. Fisher (Editor), Disease processes in marine bivalve molluscs, p. 249-256. Am. Fish. Soc., Spec. Publ. 18.

Goggins, C. L., K. B. Sewell, and R. J. G. Lester. 1989. Cross-infection experiments with Australian *Perkinsus* species. Dis. Aquat. Org. 7(1):55-59.

Harris, D. C. 1980. Survey of the intertidal and subtidal oyster resources of the Georgia coast. Ga. Dep. Nat. Resour., Coastal Resour. Div., Proj. 2-234-R, 44 p.

Haskin, H. H., and J. D. Andrews. 1988. Uncertainties and speculations about the life cycle of the eastern oyster pathogen *Haplosporidium nelsoni* (MSX). *In* W. Fisher (Editor), Disease processes in marine bivalve molluscs, p. 5-22. Am. Fish. Soc., Spec. Publ. 18.

———— and S. Ford. 1979. Development of resistance to *Minchinia nelsoni* (MSX) mortality in laboratory-reared and native oyster stocks in Delaware Bay. Mar. Fish. Rev. 41(1-2):54-63.

————, W. J. Canzonier, and J. L. Myhre. 1965. The history of "MSX" on Delaware Bay oyster grounds 1957-1965. Am. Malacol. Union Annu. Rep. 32:20-21.

————, L. A. Stauber, and J. A. Mackin, 1966. *Minchinia nelsoni* n.sp. (Haplosporida, Haplosporidiidae): Causative agent of the Delaware Bay oyster epizootic. Science 153(3742):1414-1416.

Heffernan, P. B., R. L. Walker, and J. L. Carr. 1989a. Gametogenesis cycles of three bivalves in Wassaw Sound, Georgia: I. *Mercenaria mercenaria* (Linnaeus, 1758). J. Shellfish Res. 8(1):51-60.

————, ————, and ————. 1989b. Gametogenesis cycles of three marine bivalves in Wassaw Sound, Georgia: II. *Crassostrea virginica* (Gmelin, 1791). J. Shellfish Res. 8(1):61-70.

Howard, D. W., and C. S. Smith. 1983. Histological techniques for marine bivalve mollusks. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NEC-25, 97 p.

Kern, F. G., L. C. Sullivan, and M. Takata. 1973. *Labyrinthomyxa*-like organisms associated with mass mortalities of oysters, *Crassostrea virginica*, from Hawaii. Proc. Natl. Shellfish. Assoc. 63:43-45.

Kinne, O. (Editor). 1983. Diseases of marine animals. Biol. Anst. Helgol., Hamburg, FRG, 1038 p.

Leonard, D. L., M. A. Broutman, and K. E. Harkness. 1989. The quality of shellfish growing waters on the east coast of the United States. U.S. Dep. Commer., NOAA, Off. Oceanogr. Mar. Assessment, Wash., D.C., 31 p.

Levine, N. D. 1978. *Perkinsus* gen. n. and other new taxa in the protozoan phylum Apicomplexa. J. Parasitol. 64(3):549.

Lewis, E. J. 1988. Dermo (*Perkinsus marinus*), SSO (Haplosporidium costale), and MSX (*Haplosporidium nelsoni*)—current impact on shellfish. Proc. Interstate Seafood Sem., Oct. 1987, Virginia Beach, Va., p. 113-132.

Lyles, C. H. 1969. Historical catch statistics (shellfish). U.S. Dep. Inter., Bur. Commer. Fish., Curr. Fish. Stat. No. 5007, 116 p.

Mackin, J. G. 1951. Histopathology of infection of *Crassostrea virginica* (Gmelin) by *Dermocystidium marinum* Mackin, Owen, Collier. Bull. Mar. Sci. Gulf Caribb. 1(1):72-87.

————, H. M. Owen, and A. Collier. 1950. Preliminary note on the occurrence of a new protistan parasite *Dermocystidium marinum* n.sp. in *Crassostrea virginica* (Gmelin). Science 111(2883):328-329.

McGladdery, S. E., R. J. Cawthorn, and B. C. Bradford. 1991. *Perkinsus karlssoni* n. sp. (Apicomplexa) in bay scallops *Argopecten irradians*. Dis. Aquat. Org. 10(2):127–137.

Needler, A. W. H., and R. R. Logie. 1947. Serious mortalities in Prince Edward Island oysters caused by a contagious disease. Trans. R. Soc. Can. 41(3):73-89.

Perkins, F. O. 1988. Structure of protistan parasites found in bivalve molluscs. *In* W. Fisher (Editor), Disease processes in marine bivalve molluscs, p. 93-111. Am. Fish. Soc., Spec. Publ. 18.

Quick, J. A., Jr. 1977. Fungus disease of oysters. *In* C. J. Sindermann (Editor), Disease diagnosis and control in North American marine aquaculture, p. 198-203. Elsevier Sci. Publ. Co., Amsterdam.

————, and J. G. Mackin. 1971. Oyster parasitism by *Labyrinthomyxa marina* in Florida. Fla. Dep. Nat. Resour., Mar. Res. Lab., Prof. Pap. Ser. 13, 55 p.

Ray, S. M. 1954. Biological studies of *Dermocystidium marinum* a fungus parasite of oysters. Rice Inst. Pamphl., Spec. Iss., Houston, Tex., 113 p.

————. 1966. A review of the culture method for detecting *Dermocystidium marinum*, with suggested modifications and precautions. Proc. Natl. Shellfish. Assoc. 54:55-69.

Rosenfield, A., and F. G. Kern. 1987. Shellfish management strategies to control the introduction of undesirable organisms. *In* A. White (Editor), Shellfish diseases: Current concerns in the northeast, p. 19-20. Woods Hole Oceanogr. Inst., Tech. Rep. 87-13.

Sindermann, C. J. 1970. Principal diseases of marine fish and shellfish. Acad. Press, N.Y., 369 p.

————. 1990. Principal diseases of marine fish and shellfish. Vol. 2. Diseases of marine shellfish. Acad. Press, San Diego, Calif, 516 p.

————. In press. Attitudes and activities of the International Council for the Exploration of the Sea (ICES) concerning introductions of marine organisms. *In* A. Rosenfield and R. Mann (Editors), Dispersal of living organisms into aquatic ecosystems, Md. Sea Grant Coll. Publ., Univ. Md., Coll. Park.

———— and A. Rosenfield. 1967. Principal diseases of commercially important marine bivalve mollusca and crustacea. Fish. Bull. 66(2):335-385.

Sprague, V. 1978. Comments on trends in research on parasitic diseases of shellfish and fish. Mar. Fish. Rev. 40(10):26-30.

USDOC. 1990. Fisheries of the United States, 1989. U. S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Curr. Fish. Stat. 8900, 111 p.

Walker, R. 1985. Growth and optimum seeding time for the hard clam, *Mercenaria mercenaria* (L.) in coastal Georgia. Nautilus 99(4):127-133.

———— and C. M. Humphrey. 1984. Growth and survival of the northern hard clam *Mercenaria mercenaria* (Linné) from Georgia, Virginia, and Massachusetts in coastal waters of Georgia. J. Shellfish Res. 4:125-129.

———— and K. Tenore. 1984. The distribution and production of the hard clam, *Mercenaria mercenaria*, in Wassaw Sound, Georgia. Estuaries 7(2):19-27.

Wood, J. L. and J. D. Andrews. 1962. *Haplosporidium costale* (Sporozoa) associated with a disease of Virginia oysters. Science 136(3517):710-711.

Differences in Dolphin Mortality Rates in Night and Day Sets for the U.S. Eastern Tropical Pacific Tuna Purse Seine Fishery

ATILIO L. COAN, Jr., KENNETH E. WALLACE, and ALAN R. JACKSON

Introduction

The association of yellowfin tuna, *Thunnus albacares*, with dolphins (mainly *Stenella attenuata* and *S. longirostris*) in the eastern tropical Pacific (ETP) (Fig. 1) has been used by purse seine fishermen to harvest yellowfin tuna since the early 1960's (McNeely, 1961). Purse seiners locate dolphin pods and use speed boats to herd the dolphins into purse seine nets to capture the tuna traveling below them (dolphin sets). As the dolphins are surrounded by the purse seines, some may become entangled and drown before they can be released alive (Perrin, 1969; Green et al., 1971).

While all dolphin sets start in daylight, they sometimes extend into darkness. When this occurs, more animals are killed because the release of entangled dolphins is complicated by the inability to see the animals (IATTC, 1984). Sets can also last longer (sometimes into darkness) if equipment malfunctions, strong currents, high winds, net collapses (cork lines come together, Coe et al., 1984), or canopies (net blossoms out beyond the cork line, Coe et al., 1984) occur. These problems subject dolphins to longer periods of time in the nets and contribute to higher dolphin mortality. Estimated annual dolphin mortality for the ETP international purse seine fleet was as high as 550,000 animals in 1961 (Smith, 1983) and public concern over the numbers of dolphins killed prompted the U.S. Government and U.S. industry to take steps to monitor and reduce this mortality (Fox, 1978).

Monitoring of the incidental dolphin mortality began in 1971 when the National Marine Fisheries Service (NMFS) placed scientific technicians (observers) on U.S. purse seiners fishing in the ETP. In 1979, the Inter-American Tropical Tuna Commission (IATTC) started its own international tuna-dolphin program that placed observers on both U.S. and foreign purse seiners. U.S. regulations were enacted to reduce ETP dolphin mortality through the Marine Mammal Protection Act (MMPA) in 1972, and various reauthorizations of the Act led to the establishment of the current mortality quota of 20,500 dolphins for the U.S. fleet.

Reductions in dolphin mortality were accomplished by modifying purse seines and purse seining operations (Coe et al., 1984). The "Medina panel," a portion of the purse seine net with 1-inch mesh, was developed to reduce dolphin entanglement, and backdown procedures, methods used to submerge a portion of the net, were developed to aid in the release of dolphins (Barham et al., 1977; Coe and Sousa, 1972). In the early 1980's, the U.S. tuna industry also experimented with high-intensity 140,000-lumen floodlights. These high-intensity floodlights were used to reduce dolphin mortality in dolphin sets made at night by making dolphins in the net more visible and aiding the release of captured animals. The high-intensity floodlights became a mandatory requirement for all certificated (licensed to fish on dolphins) U.S. vessels on 1 July 1986.

Our study uses data collected through the NMFS and IATTC monitoring programs, during 1979-88, to look at differences between mortality rates in day and night sets made by U.S. purse seiners fishing in the ETP. The benefits of using high-intensity floodlights to decrease night set mortality rates are assessed, a regulation aimed at eliminating night sets is simulated, and the benefits to mortality rates quantified.

Data and Methods

Data from over 20,000 dolphin sets that produced approximately 302,000 short tons (tons) of yellowfin tuna were collected by IATTC and NMFS observers on U.S. purse seiners fishing in the ETP during the period 1 January 1979 to 31 December 1988. Many types of

The authors are with the Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038.

ABSTRACT—Because dolphins sometimes travel with yellowfin tuna, Thunnus albacares, *in the eastern tropical Pacific (ETP), purse seiners use the dolphins to locate and capture tuna schools. During the process of setting the purse seine nets, dolphins often become entangled and drown before they can be released. Data for the U.S. purse seine fleet in the ETP during 1979-88 show that dolphin mortality rates in sets made during the night are higher than mortality rates in sets made during the day. Even with efforts to reduce night-set mortality rates through the use of high-intensity floodlights, night set mortality rates remain higher. The data are also used to simulate a regulation on the fishery aimed at eliminating night sets and show that dolphin mortality rates would decrease.*

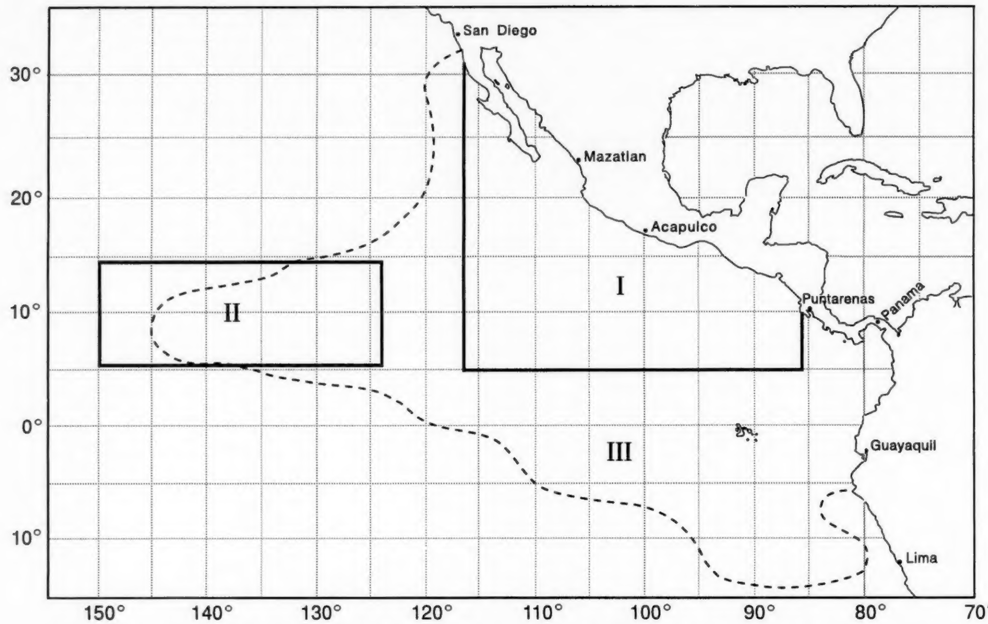

Figure 1.—Area of the eastern tropical Pacific (ETP) historically fished for yellowfin tuna associated with dolphins (dotted line) and three subareas of the ETP used to stratify data in this study and define regions of differing dolphin mortality rates. Area I is the northern coastal inshore area, area II, the offshore area, and area III is all other ETP areas.

data were collected by these observers; however, only information concerning times of various events in the set (e.g., sundown, backdown, etc.), numbers of dolphins killed, geographical location, tons of yellowfin tuna caught, and night light use for each set, was used in this analysis.

Data were divided into night sets (sets started during daylight or twilight hours but with any portion of the backdown occurring in darkness) and day sets (sets started during daylight hours and backdown procedures completed in daylight or twilight hours). For sets where no backdown information was recorded, the time of the end of the set was compared to the time of sunset, and those sets that ended before sunset were considered day sets. Those that ended after sunset were eliminated. If the time of sundown was not recorded, sundown times were calculated from the geographical position and date (Bowditch, 1966). Calculated sundown times are accurate to ±3 minutes for positions between lat. 30°N and 30°S.

In the process of separating day and night sets and computing dolphin mortality rates, certain sets were eliminated: 1) All sets where marine mammals were accidentally caught (e.g., sets on floating objects or free swimming schools of tuna where dolphins were not intentionally herded into nets); 2) sets where the tons of yellowfin caught or the numbers of marine mammals killed were not recorded; or 3) dolphin sets where there was no backdown information and the set terminated after sunset. Approximately 2% of the dolphin sets, 1% of the total dolphin mortality, and 1% of the total yellowfin tuna catch were eliminated by deleting sets that met any of these criteria.

Ninety percent (18,873) of the observed ETP dolphin sets during 1979-88 were day sets that accounted for 90% of the yellowfin tuna catch (270,916 tons) and 70% of the dolphin mortality (58,341). Night sets were much less frequent, with 10% of the dolphin sets (1,849), 10% of the yellowfin tuna catch (29,406 tons) and 30% of the dolphin mortality (25,261). The number of night sets for the entire ETP ranged from 74 to 402 and day sets from 762 to 3,891 annually (Table 1). The number of dolphins killed for the entire ETP ranged from 399 to 4,468 in night sets and 2,573 to 10,533 in day sets.

Data for night and day sets were stratified into three subareas of the ETP to assess the effects of geographical location on differences between mortality rates in day and night sets (Fig. 1). The three subareas chosen encompass regions of the ETP having significant differences in mortality rates and are standard subareas used in development of ETP dolphin fishing regulations (Federal Register, 1988, 1989). Area I contains a major portion of the northern coastal region of the ETP that is historically fished for yellowfin tuna

Table 1.—Number of sets and dolphin mortality (animals killed) for day and night sets of U.S. purse seiners fishing in the entire eastern tropical Pacific (ETP) and three subareas.

Year	Entire ETP		Area I		Area II		Area III	
	Day	Night	Day	Night	Day	Night	Day	Night
Number of sets								
1979	2,658	248	1,890	172	351	23	387	51
1980	2,023	159	1,308	103	377	30	336	26
1981	2,065	172	1,306	108	466	35	291	29
1982	1,686	206	1,011	114	217	37	451	55
1983	905	74	361	22	287	23	252	28
1984	762	104	408	51	195	32	158	21
1985	1,787	197	1,476	161	179	23	132	13
1986	1,295	162	671	90	411	47	209	25
1987	3,891	402	3,004	279	387	64	495	59
1988	1,801	168	1,197	123	137	4	467	41
Dolphin mortality								
1979	5,289	2,432	2,770	1,480	1,024	120	1,455	809
1980	4,720	1,911	1,872	427	1,198	210	1,635	1,274
1981	5,724	2,004	2,532	654	1,326	536	1,866	814
1982	6,692	2,695	2,733	1,210	493	697	3,429	788
1983	2,573	399	525	83	1,125	47	923	265
1984	2,673	2,444	1,100	1,432	662	693	911	319
1985	6,225	3,047	4,580	2,115	870	668	775	264
1986	5,781	4,468	2,263	2,106	1,512	2,042	2,001	320
1987	10,533	3,519	6,344	1,996	1,142	679	3,047	844
1988	8,131	2,342	3,978	615	1,136	10	3,017	1,717

associated with dolphins. Area II contains the offshore region, and area III contains all other regions of the ETP not contained in areas I or II.

Sixty-seven percent of the observed ETP dolphin sets during 1979-88 occurred in area I, 16% in area II, and 17% in area III (Table 1). Forty-nine percent of the dolphin mortality occurred in area I, 19% in area II, and 32% in area III. The average number of observed night and day sets (32 and 301) and dolphin mortality (570 and 1,049) was lowest in area II.

Dolphin night sets were divided into sets using high-intensity floodlights and sets using other types of lights (e.g., low-intensity lights). Data for 722 night sets that used high-intensity floodlights were available for 1982-88 only and ranged from a low of 9 in 1983 to a high of 327 in 1987. Data for 451 night sets that used other types of light were available for 1982-88 and ranged from a low of 21 in 1988 to a high of 146 in 1982. In 1982-86, high-intensity floodlights were loaned to only a select group of vessels to test their usefulness. After 1986 the lights were available to all vessels. Due to the limited number of sets that used high-intensity floodlights or other types of light, comparisons of mortality rates for these sets were not stratified by subareas of the ETP.

Two mortality rates were calculated: The total number of dolphins killed divided by the total number of dolphin sets (kill/set); and total number of dolphins killed divided by the total tonnage of yellowfin tuna caught (kill/ton) in dolphin sets. Percentages of dolphin sets with zero dolphins killed (zero-kill sets) and percentages of dolphin sets with more than 15 dolphins killed (high-kill sets) were also calculated.

The Wilcoxon paired-sample test (Zar, 1974; Siegel, 1956) was used to determine significant differences (at the 5% level) between the following pairs of data: 1) Mortality rates in day sets vs. night sets, 2) percentages of high-kill sets in day sets vs. night sets, 3) percentages of zero-kill sets in day sets vs. night sets, and 4) mortality rates in sets that used high-intensity floodlights vs. sets that used other types of light. The pairs of data considered were yearly estimates. The test considers the magnitude and occurrences of positive and negative differences between the estimates in determining whether the differences are randomly distributed. The null hypothesis was that the estimated mortality rates, percentages of zero-kill sets, and percentages of high-kill sets were the same in day and night sets, or that the mortality rates in night sets that used high-intensity floodlights and those that used other types of lights were the same. A nonparametric statistical test was chosen because estimated mortality rates were not normally distributed. The distributions were basically Poisson with the major mode occurring at zero dolphins killed (Fig. 2).

Linear regressions were used to define trends in yearly estimates of mortalities and mortality rates. These trends were considered significant (5% level) if the regression coefficients were statistically different from zero. The Student's T statistic was used to determine significance. To guarantee that the regression coefficients were of minimum variance, autocorrelation was assessed with a Runs test and Durbin-Watson statistic on the residuals (Smillie, 1966).

Results

The number of observed sets and dolphin mortality in most areas of the ETP was highest in 1987, when observer coverage was 92% and lowest in 1983 (31% observer coverage) or 1984 (28% observer coverage), when a court injunction limited the placement of observers. While this relationship of higher estimates in high coverage years and lower estimates in low coverage years may imply an autocorrelation between coverage rates and mortality and mortality rate estimates, no positive or negative autocorrelation was detected at the 5% level of significance. Therefore, esti-

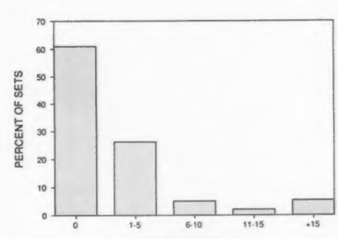

Figure 2.—A typical distribution of mortality rates in dolphin sets of U.S. purse seiners fishing in the eastern tropical Pacific.

Table 2.—Statistical comparisons of mortality rates and percentages of zero-kill and high-kill (more than 15 dolphins killed) sets in the entire eastern tropical Pacific and three subareas. Values of the Wilcoxon's T statistic greater than eight are considered significant at the 5% level, except for high-intensity light comparisons that are significant if values are greater than three.

Comparison	Wilcoxon's T statistic	Conclusion
Kill/set day vs. night		
Entire ETP	0	Night sets higher
Area I	0	Night sets higher
Area II	5	Night sets higher
Area III	0	Night sets higher
Kill/ton day vs. night		
Entire ETP	0	Night sets higher
Area I	0	Night sets higher
Area II	5	Night sets higher
Area III	0	Night sets higher
% Zero-kill sets day vs. night		
Entire ETP	0	Night sets lower
Area I	0	Night sets lower
Area II	0	Night sets lower
Area III	3	Night sets lower
% High-kill sets day vs. night		
Entire ETP	0	Night sets higher
Area I	0	Night sets higher
Area II	4	Night sets higher
Area III	1	Night sets higher
High-intensity lights vs. other lights		
Kill/set entire ETP	0	Other light higher
Kill/ton entire ETP	1	Other light higher
High-intensity lights vs. day sets		
Kill/set entire ETP	0	High-intensity light higher
Kill/ton entire ETP	1	High-intensity light higher
Kill/set Area I vs. Area II		
Day sets	2	Area II higher
Night sets	13	No significant difference
Kill/set Area I vs. Area III		
Day sets	0	Area III higher
Nights sets	13	No significant difference
Kill/set Area II vs. Area III		
Day sets	6	Area III higher
Night sets	18	No significant difference
Kill/ton Area I vs. Area II		
Day sets	13	No significant difference
Night sets	26	No significant difference
Kill/ton Area I vs. Area III		
Day sets	0	Area III higher
Night sets	15.5	No significant difference
Kill/ton Area II vs. Area III		
Day sets	4.5	Area III higher
Night sets	15	No significant difference
Zero-kill Area I vs. Area II		
Day sets	0	Area I higher
Night sets	0	Area I higher
Zero-kill Area I vs. Area III		
Day sets	6	Area I higher
Night sets	0	Area I higher
Zero-kill Area II vs. Area III		
Day sets	1	Area II higher
Night sets	19	No significant difference
High-kill Area I vs. Area II		
Day sets	6	Area I lower
Night sets	15	No significant difference
High-kill Area I vs. Area III		
Day sets	0	Area I lower
Night sets	4	Area I lower
High-kill Area II vs. Area III		
Day sets	1	Area II lower
Night sets	12	No significant difference

mates of mortality rates and mortalities are randomly ordered and independent of yearly coverage rates, and trends generated from simple regressions will properly estimate the variance.

ETP night set dolphin mortality rates (kill/set and kill/ton) were significantly higher than ETP day set mortality rates during 1979-88 (Table 2). Day set kill/set ranged from 1.99 to 4.51 dolphins per set and for night sets from 5.39 to 27.58 dolphins per set (Fig. 3). Day set kill/ton ranged from 0.19 to 0.38 dolphins/ton and for night sets from 0.5 to 1.31 dolphins/ton. A significant increasing trend during 1979-88, was detected in kill/set for day sets (Table 3).

Night set mortality rates were significantly higher in all three subareas of the ETP than day set mortality rates (Table 2). Dolphin mortality rates in day sets were generally lower in area I than in areas II and III, whereas no significant differences in night set mortality rates between areas were detected. Mortality rates were highest in area III in 1980 when kill/set was 49 dolphins/set and kill/ton was 4.39 dolphins/ton. Night set mortality rates were always higher than day set mortality rates, except in area II in 1983 and 1988 (Fig. 3). Significant increasing trends during 1979-

Table 3.—Kill/set and kill/ton for day and night sets in the entire eastern tropical Pacific (ETP) and three subareas. The Student's T statistic is used to detect significant trends in the data. Values greater than ±2.306 are significant at the 5% level. Positive values indicate increasing trends and negative values reflect decreasing trends.

	Entire ETP		Area I		Area II		Area III	
Year	Day	Night	Day	Night	Day	Night	Day	Night
Kill/set								
1979	1.99	9.81	1.46	8.60	2.92	5.22	3.76	15.86
1980	2.33	12.02	1.43	4.14	3.18	7.00	4.87	49.00
1981	2.77	11.65	1.94	6.06	2.84	15.31	6.41	28.07
1982	3.97	13.08	2.70	10.61	2.27	18.84	7.60	14.32
1983	2.84	5.39	1.45	3.77	3.92	2.04	3.66	9.46
1984	3.51	23.50	2.70	28.08	3.39	21.66	5.76	15.19
1985	3.48	15.47	3.10	13.14	4.86	29.04	5.87	20.31
1986	4.46	27.58	3.37	23.40	3.68	43.45	9.57	12.80
1987	2.71	8.75	2.11	7.15	2.95	10.61	6.16	14.30
1988	4.51	13.94	3.32	5.00	8.29	2.50	6.46	41.88
Student's T	2.74	0.97	3.04	0.68	2.24	0.78	1.56	−0.24
Kill/ton								
1979	0.20	0.79	0.16	0.83	0.25	0.47	0.26	0.87
1980	0.23	1.09	0.18	0.43	0.22	0.45	0.37	4.39
1981	0.26	1.02	0.21	0.63	0.22	0.93	0.48	2.25
1982	0.38	0.98	0.31	1.03	0.19	1.17	0.55	0.80
1983	0.28	0.50	0.22	0.55	0.30	0.18	0.29	0.68
1984	0.18	1.31	0.15	1.82	0.17	1.07	0.28	0.75
1985	0.20	0.81	0.18	0.71	0.20	1.24	0.44	1.12
1986	0.15	1.03	0.17	0.92	0.12	1.39	0.41	0.55
1987	0.26	0.50	0.13	0.45	0.13	0.54	0.31	0.68
1988	0.19	0.76	0.20	0.29	0.44	0.17	0.34	1.95
Student's T	−0.88	−0.85	−0.69	−0.35	0.27	0.15	−0.21	−1.11

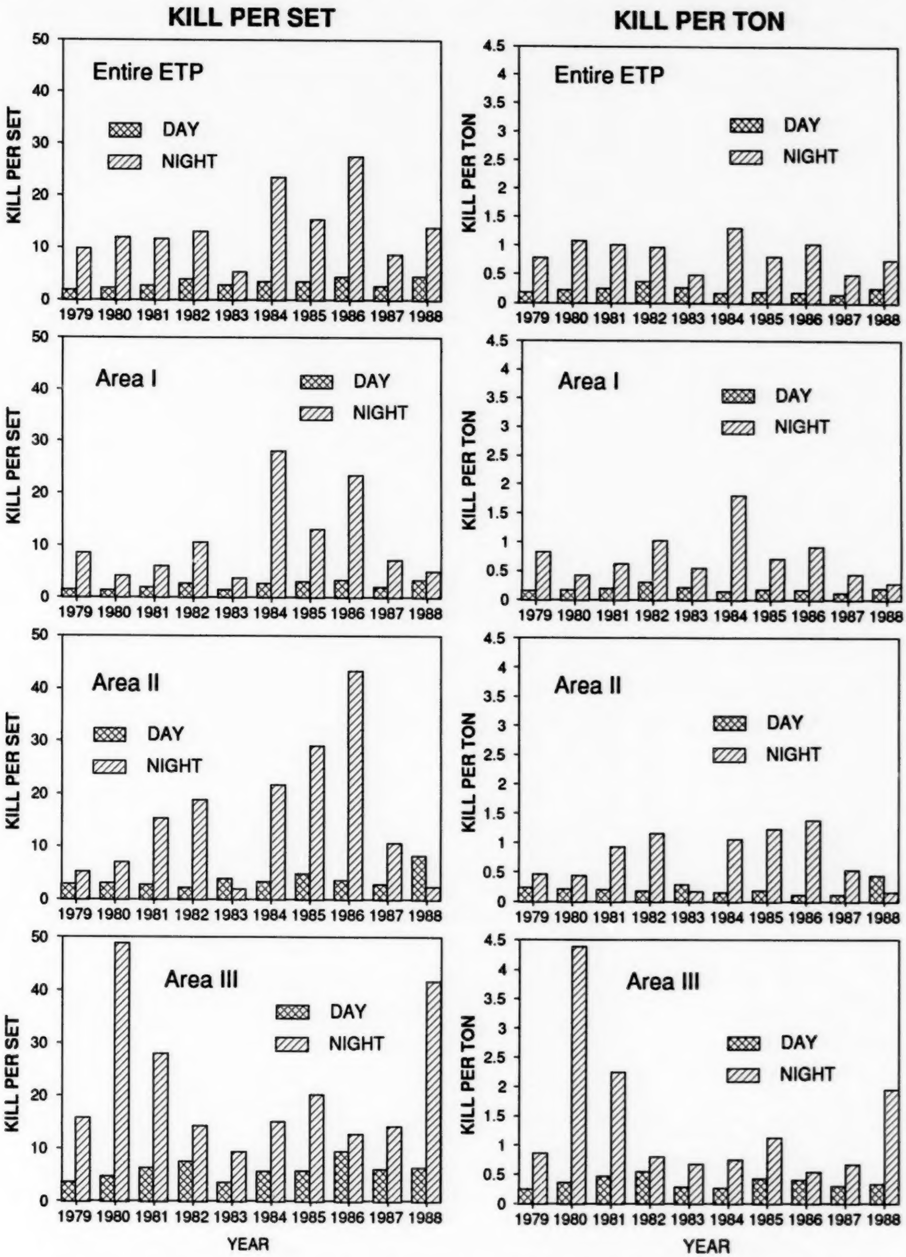

Figure 3.—Kill/set and kill/ton in day and night sets of U.S. purse seiners fishing in the eastern tropical Pacific (ETP) and three subareas of the ETP.

88 were detected in kill/set for day sets in area I only (Table 3).

Day sets in the ETP had significantly higher percentages of zero-kill sets and lower percentages of high-kill sets than night sets (Table 2). Night set zero-kill percentages ranged from 36 to 51%, whereas day set percentages ranged from 52 to 71% (Figure 4). Percent-

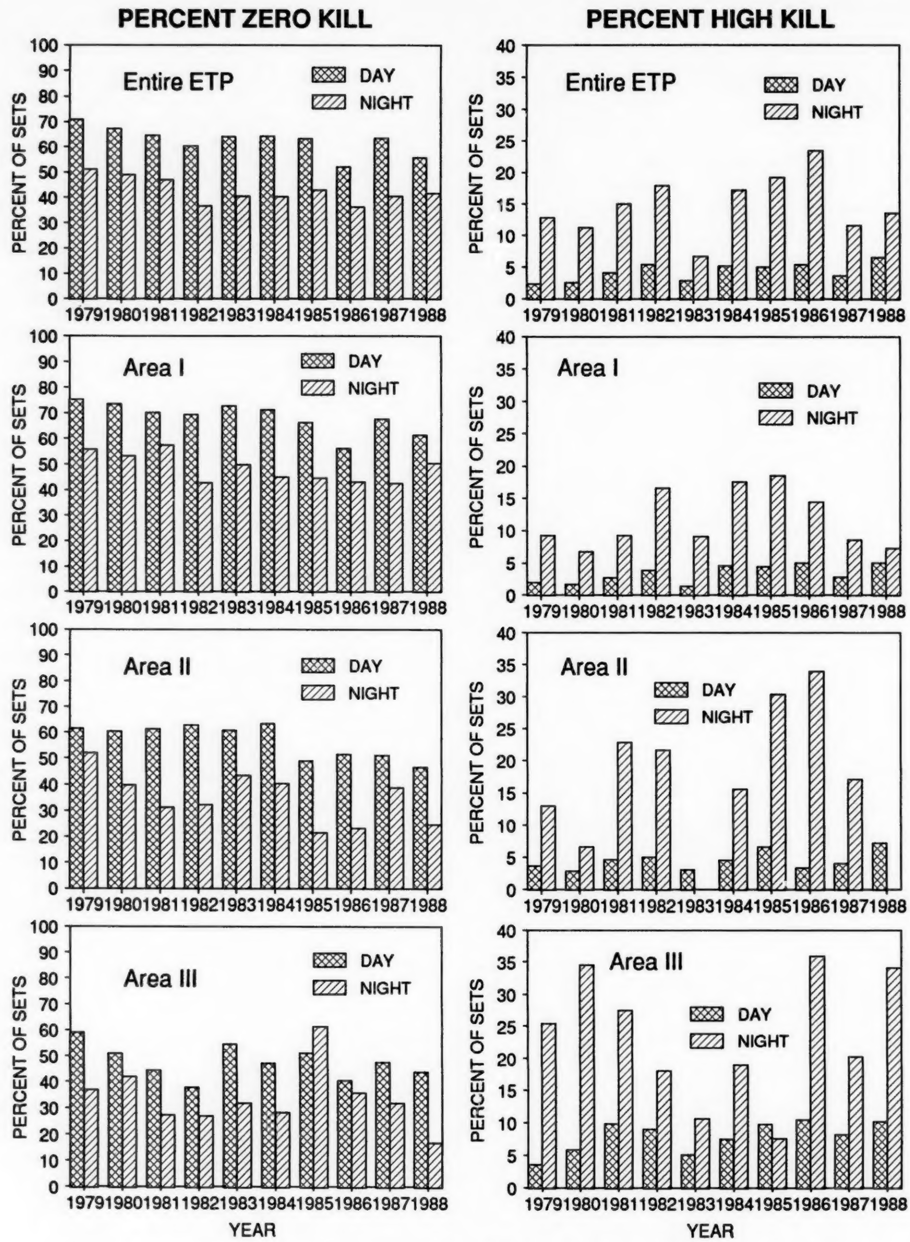

Figure 4.—Percentages of zero-kill sets and high-kill sets in day and night sets of U.S. purse seiners fishing in the eastern tropical Pacific (ETP) and three subareas of the ETP.

ages of high-kill sets ranged from 7 to 23% for night sets and 2 to 7% for day sets. The greatest differences between the percentages occurred in zero-kill sets, where day sets were as much as 20% higher than night sets. Significant decreasing trends in both day and night set percentages of zero-kill sets during 1979-88, were detected (Table 4).

Stratified percentages of zero-kill sets in night sets were significantly lower than in day sets for all subareas

Table 4.—Percentages of zero-kill sets and high-kill sets (more than 15 dolphins killed) for day and night sets in the entire eastern tropical Pacific (ETP) and three subareas. The Student's T statistic detects significant trends in the data. Values greater than ±2.306 are significant at the 5% level. Positive values indicate increasing trends and negative values reflect decreasing trends.

	Entire ETP		Area I		Area II		Area III	
Year	Day	Night	Day	Night	Day	Night	Day	Night
Zero-kill:								
1979	71.07	51.21	75.34	55.81	61.82	52.17	59.43	37.25
1980	67.47	49.06	73.70	53.40	60.74	40.00	51.19	42.31
1981	64.75	47.09	70.29	57.41	61.59	31.43	44.67	27.59
1982	60.26	36.89	69.44	42.98	63.13	32.43	38.14	27.27
1983	64.20	40.54	72.85	50.00	60.98	43.48	54.76	32.14
1984	64.44	40.38	71.32	45.10	63.59	40.62	47.47	28.57
1985	63.51	43.15	66.33	44.72	49.16	21.74	51.52	61.54
1986	52.12	36.42	56.18	43.33	51.58	23.40	40.67	36.00
1987	63.61	40.55	67.74	42.65	51.16	39.06	47.88	32.20
1988	55.91	41.67	61.57	50.41	46.72	25.00	44.11	17.07
Student's T	−3.01	−2.53	−3.44	−2.34	−4.04	−2.17	−1.31	−0.50
High-kill:								
1979	2.41	12.90	1.96	9.30	3.70	13.04	3.62	25.49
1980	2.62	11.32	1.68	6.80	2.92	6.67	5.95	34.62
1981	4.21	15.12	2.76	9.26	4.72	22.86	9.97	27.59
1982	5.46	17.96	3.86	16.67	5.07	21.62	9.09	18.18
1983	2.98	6.76	1.39	9.09	3.14	0.00	5.16	10.71
1984	5.25	17.31	4.66	17.65	4.62	15.62	7.59	19.05
1985	5.09	19.29	4.47	18.63	6.70	30.43	9.85	7.69
1986	5.41	23.46	5.07	14.44	3.41	34.04	10.53	36.00
1987	3.68	11.69	2.86	8.60	4.13	17.19	8.28	20.34
1988	6.61	13.69	5.10	7.32	7.30	0.00	10.28	34.15
Student's T	−0.88	−0.85	−0.69	−0.35	0.27	0.15	−0.21	−1.11

of the ETP, and percentages of high-kill sets in night sets were significantly higher than in day sets (Table 2). Percentages of zero-kill sets were significantly lower for both day and night sets in areas II and III than in area I. However, areas II and III generally had significantly higher percentages of high-kill sets than area I. Percentages of zero-kill sets were always lower in night sets than in day sets except for area III in 1985 (Fig. 4). Percentages of high-kill sets were always higher in night sets than in day sets, except in 1983 and 1988 in area II, and 1985 in area III. Significant decreasing trends were found in the percentages of zero-kill sets for day sets in areas I and II and for night sets in area I (Table 4).

Comparisons of Floodlight Use in Night Sets

During 1982-88, night sets using high-intensity floodlights generally produced significantly lower mortality rates (4-77%) than night sets using other types of lights (Table 2). Only in 1985 did kill/ton for night sets that used other lights fall below kill/ton in night sets that used high-intensity floodlights (Fig. 5). The greatest difference occurred in 1984 when kill/set in sets using high-intensity floodlights was approximately 77% lower than kill/set in sets using other types of light. High-intensity floodlights were therefore effective in reducing night set mortality rates. However, mortality rates were

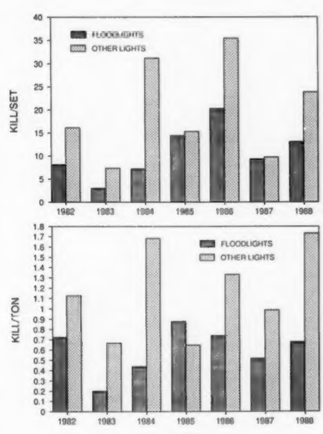

Figure 5.—Kill/set and kill/ton in night sets of U.S. purse seiners fishing in the eastern tropical Pacific that used high-intensity floodlights or other types of lights.

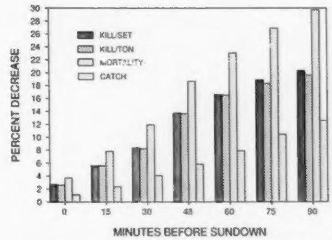

Figure 6.—Percent decreases in kill/set, kill/ton, dolphin mortality, and yellowfin catch if sets beginning after sundown or at various times before sundown (e.g., 15, 30, 45, etc., minutes) were eliminated from dolphin sets made by U.S. purse seiners fishing in the eastern tropical Pacific during the period 1979 to 1988.

still significantly lower in day sets (Table 2).

Effects of Prohibiting Night Sets

Night sets begin before sundown or during the twilight hours, while herds of dolphins can still be seen, extend into darkness, and are usually completed before midnight. Regulations prohibiting these night sets were simulated by selecting time limits (sundown and 15, 30, 45, 60, 75, and 90 minutes before sundown), eliminating both day and night sets starting after each of these time limits and calculating and comparing the new total (day and night sets combined) mortality rates to rates before any sets were eliminated.

Results showed that average total mortality rates for 1979-88, decreased approximately 6-20% (Fig. 6), depending on the time limit chosen. Total mortality decreased as much as 30% and catches dropped 13%.

The simulation did not eliminate all night sets. Even by prohibiting sets starting after 90-minutes before sun-

down, 144 night sets that killed 3,651 animals still remained. Some of these sets started as much as 5 hours before sundown and, because of problems during the set or other reasons, extended into darkness. The resulting average kill/set of 25 dolphins per set for these sets was almost 79% higher than the average kill/set in the ETP (14 dolphins/set) before any night sets were eliminated.

The simulation also eliminated valid day sets that started after the time limits and, because operations went so quickly, were completed before darkness. Under the 90-minute set prohibition, 705 sets or approximately 4% of the valid day sets were lost along with 4% (9,800 tons) of the yellowfin tuna catch.

Discussion

Our results show that night sets, while contributing only 30% of the observed mortality, killed animals at a significantly higher rate than day sets. Stratification of the data by the three subareas did not change these results.

Factors such as proximity of the start of the set to sundown, size of the yellowfin catch, and problems that occur during dolphin sets extend sets into darkness where higher mortalities occur. Fishermen have tried to reduce the effects of darkness in night sets through the use of high-intensity floodlights. While these lights decreased mortality rates in night sets by making animals in the net more visible, mortality rates in sets using these lights were still significantly higher than day set mortality rates, probably because animals that are usually seen in daylight, i.e., just below the surface and at the fringes of the lighted area, still go undetected.

It appears that all past efforts to eliminate the significant differences between day and night set mortality rates failed, probably due to the unique factor that darkness plays in making dolphins more vulnerable during night sets. However, our study shows that through regulations aimed at reducing the number of night sets while minimizing the effect on day sets, substantial decreases in overall mortality rates (day and night sets combined) can be attained. Since some night sets would still occur under these regulations, additional decreases in mortality rates could be made if they were eliminated.

Acknowledgments

We would like to thank the following people for their contributions to the completion of this paper: Bob Salomons of LMR Fisheries Research who supplied many of the refinements to the data; Jim Joseph, Martin Hall, Dave Bratten, and Susan Boyer of the IATTC for data collected from the IATTC observer program; Mike Trianni and Randy Rasmussen for help with the NMFS data; Rick Tauber for programming assistance; Nancy Lo and Bruce Wahlen for their statistical consultation, and lastly, Chuck Oliver and James Coe for preliminary work on sundown sets that contributed to the development of this paper.

Literature Cited

Barham, E. G., W. K. Taguchi, and S. B. Reilly. 1977. Porpoise rescue methods in the yellowfin purse seine fishery and the importance of the Medina panel mesh size. Mar. Fish. Rev. 39(5):1-10.

Bowditch, N. 1966. American practical navigator. U.S. Gov. Print. Off., Hydrogr. Off. Publ. 9, 1,524 p.

Coe, J., and G. Sousa. 1972. Removing porpoise from a tuna purse seine. Mar. Fish. Rev. 34(11-12):15-19.

————, D. B. Holts, and R. W. Butler. 1984. The "tuna porpoise" problem: NMFS dolphin mortality reduction research, 1970-81. Mar. Fish. Rev. 46(3):18-33.

Federal Register. 1988. Regulations governing the importation of tuna taken in association with marine mammals. U.S. Dep. Commer., NOAA. Fed. Regist. 53(53):8910-8920.

————. 1989. Regulations governing the importation of tuna taken in association with marine mammals. U.S. Dep. Commer., NOAA. Fed. Regist. 54(43):9438-9451.

Fox, W. W., Jr. 1978. The tuna-dolphin program: Five years of progress. Oceans 11(3):57-59.

Green, R. E.,W. F. Perrin, and B. P. Petrich. 1971. The American tuna purse seine fishery. *In* H. Kristjonsson (Editor), Modern fishing gear of the world 3, p. 182-194. Fish. News (Books) Ltd., Lond.

IATTC. 1984. Annual report of the Inter-American Tropical Tuna Commission, 1983. Inter-Am. Trop. Tuna Comm., La Jolla, Calif., 272 p.

McNeely, R. L. 1961. Purse seine revolution in tuna fishing. Pac. Fish. 59(7):27-56.

Perrin, W. F. 1969. Using porpoise to catch tuna. World Fish. 18(6):42-45.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw Hill, N.Y., 312 p.

Smillie, K. W. 1966. An introduction to regression and correlation. The Ryerson Press, Toronto, and Acad. Press, N.Y., 168 p.

Smith, T. D. 1983. Changes in size of three dolphin (*Stenella* spp.) populations in the eastern tropical Pacific. Fish. Bull., 81:1-13.

Zar, J. H. 1974. Biostatistical analysis. Prentice Hall, Inc., NJ., 620 p.

The U.S. Gulf of Mexico Party Boat Industry: Activity Centers, Species Targeted, and Fisheries Management Opinions

ROBERT B. DITTON, STEPHEN M. HOLLAND, and DUANE A. GILL

Introduction

Throughout the U.S. Gulf of Mexico and elsewhere, party boats provide anglers with a relatively low-cost means of accessing nearshore and offshore fishing. In contrast with charter boats, Fraser et al. (1977) reported that party boats are larger, carry more passengers (≤150 anglers), fish for bottom fish, are operated on a schedule, and their captains prefer to operate with as many anglers on board as possible to maximize income. Finally, they vary by the way fees are charged. Party boats charge on a per-head basis (referred to as head boats in some areas) in contrast to charter boats which charge for the rental of the boat with captain and mate. Party boat fees range from $15 to about $70 whereas charter boat fees are usually ≥$300.

Robert B. Ditton is with the Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843. Stephen M. Holland is with the Department of Recreation, Parks and Tourism, University of Florida, Gainesville, FL 32611. Duane A. Gill is with the Department of Sociology/Anthropology and Social Science Research Center, Mississippi State University, Mississippi State, MS 39762. Views or opinions expressed or implied are those of the authors and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA.

ABSTRACT—In addition to providing an overview of the party boat fishery in the U.S. Gulf of Mexico, a management-oriented methodology is presented that can be used elsewhere to assess regulatory impacts. Party boat operators were interviewed to determine species targeted, percent time committed to targeting each species, and opinions on current catch restrictions. Over two-thirds of the fleet was located on the west coast of Florida. Overall, most boats targeted ≤5 species. Four species accounted for 90 percent of the estimated effort by party boats in the U.S. Gulf of Mexico: Snapper, Lutjanus *sp.; grouper,* Epinephelus *sp. and* Mycteroperca *sp.; amberjack,* Seriola dumerili*; and king mackerel,* Scomberomorus cavalla. *Party boat effort in Texas was devoted primarily to snapper, whereas in Florida most effort was devoted to snapper and grouper collectively. Party boat operators were diverse in their opinions of management regulations in force when interviewed. Results revealed why major opposition would be expected from Texas party boat operators for red snapper bag limits and other restrictions proposed by the Gulf of Mexico Fishery Management Council.*

Because of overutilization by various user groups in the U.S. Gulf of Mexico, some fish stocks are stressed and require management attention. During the past 10 years, the Gulf of Mexico Fishery Management Council (GMFMC) has developed fishery management plans (FMP's) in accordance with criteria specified in the Magnuson Fishery Conservation and Management Act (MFCMA) (16 U.S.C. 1801 et seq.). Consequently, operating a party boat today is complicated. Language and communication are increasingly complex and reflect concerns for legal precision and scientific support. In this regard, captains are faced with "acronyms, computer output, statistical calculations and bureaucratic jargon" (Miller and Van Maanen, 1983). Stock assessment results are used by the GMFMC to determine Allowable Biological Catch (ABC) which in turn provides the basis for establishing Total Allowable Catch (TAC). The TAC ultimately impacts party boat operations in terms of minimum size regulation, bag limits, and closures when recreational allocations are met. For example, red snapper, *Lutjanus campechanus*, were unmanaged in the Exclusive Economic Zone (EEZ) until November 1984 when the Reef Fish Fishery Management Plan (FMP) was implemented. Among other requirements, the reef fish FMP established a minimum size limit of 13 inches total length for red snapper with an incidental catch of 5 red snappers <13 inches in total length per person per trip (50 CFR 641). Party boats were exempted from size and bag limits until May 1987 due to their dependence on red snapper. The incidental catch allowance was eliminated in February 1990 leaving the minimum size requirement in force. The FMP was amended "to reduce fishing mortality on the reef fish stocks so that stocks may be protected and rebuilt, to reduce user conflicts, and to maximize net economic benefits from the reef fishery" (55 FR 2090-2091). In April 1990, a 7-fish bag limit was implemented and was expected to remain in effect through 1991. This scenario of increasingly stringent regulations is occurring with numerous other species targeted by Gulf party boats.

New and proposed regulations[1] have created uncertainty for party boat operators because they do not know if there is a market for a fishing experi-

[1]55 Fr 2078-2094, Amendment number 2 to the Fishery Management Plan for reef fish, 1989, and Draft. Plan amendment 3 of the reef fish Fishery Management Plan (including environmental assessment, regulatory impact review, and regulatory flexibility analysis). 1990. Gulf of Mexico Fishery Management Council, Lincoln Center, Suite 881, 5401 West Kennedy Blvd., Tampa, FL 33609.

ence with reduced bag limits. If, as reported by Carls (1976) and Ditton and Gill (1988), party boat patrons are more highly motivated by catch motivations than other noncatch angler motives, reduced bag limits may lead to drop-outs in existing clientele and a need to attract new and less catch-oriented customers. Since most party boat operations lack a marketing capability (Ditton and Gill, 1988), their main alternatives are to quit business, oppose new management regulations, and when regulations are implemented, target other species. The latter alternative is no longer viable in the Gulf of Mexico as nearly all offshore species are currently regulated.

Whereas new fishery regulations can be expected to have some impact on party boat operators (among others in the fishery), some operators may be impacted more than others. Party boat operators are not likely to be uniformly distributed across the U.S. Gulf of Mexico. Species targeted are likely determined by abundance and angling custom. When catch regulations are implemented, party boat operations that depend on regulated species in areas of abundance are impacted whereas others are not because they target other fish stocks. Also, when migratory stocks are involved, some operators may not have an opportunity to target a particular species prior to closure by virtue of their geographical location.

Most research in the U.S. Gulf of Mexico regarding party boat operations has been insufficient for regional fisheries management purposes, especially assessment of regulatory impacts assessment. Most research has been completed in Texas and Florida and has focused on fleet revenues and economic impacts (Destin Chamber of Commerce[2]; Prochaska and Cato, 1975), business operations (Schmied, 1975; Woods, 1977), or catch (McEachron and Matlock, 1983; McEachron, 1984). None of these studies involved more than one discipline or state. Only one study (Browder et al., 1978) comprehensively addressed party boat operations. This study identified party boat activity centers on the west coast of Florida and examined social and economic characteristics of operators, target species utilized, and changes in target species by season. This approach was partially replicated by Ditton et al. (1988) and Holland and Milon (1989) to provide coverage for the U.S. Gulf of Mexico. Data presented in this paper were taken from these two studies.

The purpose of this paper was to characterize the party boat fishery in the U.S. Gulf of Mexico and provide a baseline for understanding fishery trends. Further, in light of allocation decisions being made, there is a need to understand variations by state in the size and distribution of the party boat fleet, species targeted, estimated fishing pressure, and operator opinions regarding existing regulations. Also, this paper presents a management-oriented methodology that can be used elsewhere to assess regulatory impacts.

Methods

Initially, we determined there were 97 party boats in the five states adjacent to the U.S. Gulf of Mexico. Because of the low number of boats, we sought to interview operators of all party boats in Texas, Louisiana, Mississippi, and Alabama (n=31) and drew a random sample of 18 of 66 party boats in Florida. The sampling frame was derived from the 1985 and 1986 vessel canvas conducted by the NMFS Southeast Fisheries Center, the list of party boats maintained by the NMFS Southeast Regional Office and Panama City Laboratory, and on-site information provided by NMFS and project personnel. Information was merged to produce a final list of party boats and operators without duplicates. Letters were sent to operators of all boats selected to explain the intent of the survey and encourage participation. The initial population of party boats was later adjusted downward for boats no longer in business.

A 19-page interview schedule was developed to collect information on the operator's background and demographics, boat description, species information, operating policy, boat operation, business structure, community ties, and opinions on current regulations. An initial interview schedule was pretested in March 1987 with 8 operators in Texas. Revisions were made as a result of this pretest.

In this paper we focus on data concerning species targeted, percent time devoted to targeting each species, and opinions toward current catch restrictions on select species. First, for each boat sampled, operators were given a listing of 23 species and asked to indicate which ones were targeted during each of the previous 12 months. Second, they were asked "what percent of your time fishing was devoted to targeting each of these species" during each of four 3-month periods. Percent time targeting for each 3-month period was additive to 100 percent. Finally, using a 5-point balanced Likert-type scale, operators were asked whether they supported or opposed current recreational catch restrictions on six species.

Party boat operators in Texas, Louisiana, Mississippi, and Alabama were interviewed by trained field personnel during May-August 1987. Operators in Florida were interviewed during February-July, 1988. Each interview took 30-40 minutes to complete per boat. Operators were contacted prior to travel to schedule interviews during weekday periods. Nevertheless, second and third follow-up trips had to be scheduled with operators missed on initial visits.

Interviews were completed with 17 operators (65 percent) of an adjusted population of 26 party boats in Texas, Louisiana, Mississippi, and Alabama. Boat operators not interviewed were busy running trips or refused to participate. In Florida, interviews were completed with operators of 21 (32 percent) of 66 party boats. For confidentiality purposes, data for boats in Louisiana, Mississippi, and Alabama were aggregated because there were <5 boats per state.

Results

Over two-thirds of the party boat fleet in the U.S. Gulf of Mexico is located on the west coast of Florida (Fig. 1, Table 1). Major activity centers

[2]Destin Chamber of Commerce. 1969. The potential of the Destin, Florida fare-carrying fishing fleet. Unpubl. rep., 8 p.

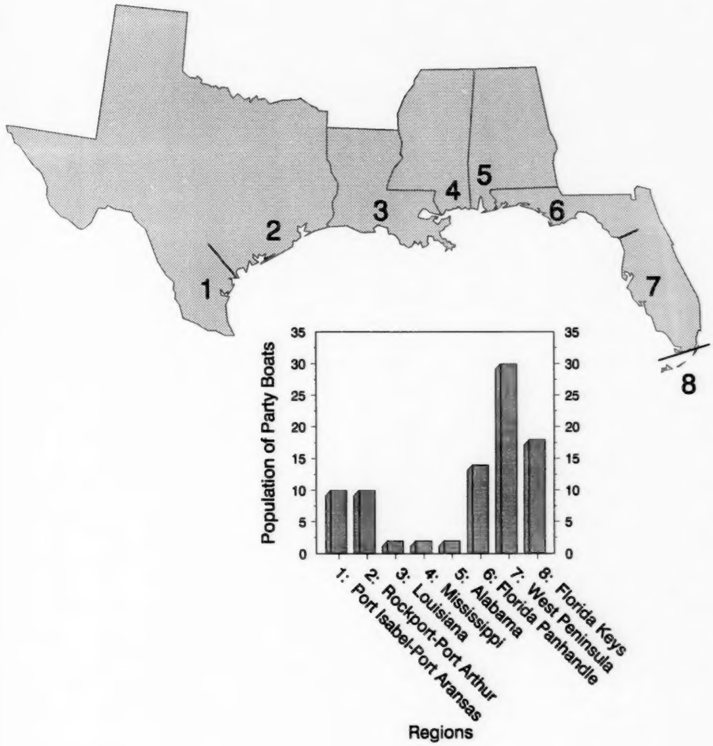

Figure 1.—Regional distribution of party boats in the U.S. Gulf of Mexico.

Table 1.—Distribution of population of party boats in the U.S. Gulf of Mexico by state and area.

	Population	
State and area	No.	Percent
Texas		
1. Port Isabel-Port Aransas	10	
2. Rockport-Port Arthur	10	
Subtotal	20	22.7%
Northern Gulf States		
3. Louisiana	2	2.3
4. Mississippi	2	2.3
5. Alabama	2	2.3
Florida		70.4
6. Panhandle	14	
7. West Peninsula	30	
8. Keys	18	
Subtotal	62	
Grand total	88	100.0

(number of boats) in Florida include the Keys; the Marco Island, Naples, and Ft. Myers area; and the Madeiria Beach, Clearwater, and St. Petersburg area. Most of the 20 boats in Texas were located in the Galveston-Freeport area. By extrapolation, we estimated the number of trips and passengers taken offshore in the previous 12 months by the population of party boats in each state or region: Texas—1,858 trips, 34,373 passengers; northern Gulf states—150 trips, 2,775 passengers; Florida—17,329 trips, 320,587 passengers. If we assume 92 percent of party boat passengers went to fish (Carls, 1976), party boats took an estimated 329,116 anglers offshore in the U.S. Gulf of Mexico.

Table 2.—Distribution of number of species targeted by the extrapolated number of party boats in the U.S. Gulf of Mexico during a 1-year period by state or region.

No. of species targeted	Texas		N. Gulf states[1]		Fla.		U.S. Gulf	
	No.	%	No.	%	No.	%	No.	%
1	6	30.0	0	0.0	4	6.5	10	11.4
2	8	40.0	1	16.6	8	12.9	17	19.3
3	2	10.0	1	16.6	4	6.5	7	7.9
4	2	10.0	2	33.3	0	0.0	4	4.5
5	0	0.0	0	0.0	8	12.9	8	9.1
6	0	0.0	2	33.3	8	12.9	10	11.4
7	0	0.0	0	0.0	0	0.0	0	0.0
8	0	0.0	0	0.0	8	12.9	8	9.1
9	0	0.0	0	0.0	0	0.0	0	0.0
10	0	0.0	0	0.0	8	12.9	8	9.1
>10	2	10.0	0	0.0	14	22.5	16	18.2
	20	100.0	6	99.9	62	100.0	88	100.0

[1]Louisiana, Mississippi, Alabama.

There is diversity within the region in number of species targeted. Whereas 80 percent of the boats targeted ≤3 species in Texas, this was the case for only 33 percent and 26 percent of the boats in the northern Gulf states area and Florida, respectively (Table 2). Gulfwide, most party boats targeted ≤5 species.

Snapper, *Lutjanus* sp.; grouper, *Epinephelus* sp. and *Mycteroperca*, sp.; and amberjack, *Seriola dumerili* (in decreasing order of selection) were targeted by ≥35 party boats (Table 3). Most boats in Texas targeted snapper. Boats in Florida targeted snapper and grouper. In the northern Gulf states, most boats

Table 3.—Number of party boats operating from Texas and the northern Gulf states (1986-87) and Florida (1987-88) and in the U.S. Gulf of Mexico by species targeted.

	Number of party boats			
Species	Texas	N. Gulf states	Florida	U.S. Gulf
Amberjack	2	1	37	40
Barracuda	0	1	21	22
Blackfin tuna	2	1	12	15
Blue marlin	3	1	8	12
Bluefin tuna	2	1	4	7
Bluefish	0	4	4	8
Bonito	2	2	29	33
Cobia	0	1	25	26
Dolphin	3	1	29	33
Flounder	0	1	17	18
Grouper	3	2	58	63
King mackerel	8	3	17	28
Ladyfish	0	1	8	9
Red drum	0	5	8	13
Sailfish	3	1	12	16
Shark	2	2	25	29
Snapper	17	1	58	76
Spanish mackerel	2	5	17	24
Spotted sea trout	0	4	8	12
Swordfish	2	1	8	11
Wahoo	0	1	8	9
White marlin	3	1	8	12
Yellowfin tuna	2	1	8	11

targeted red drum *Scianops ocellatus* and spotted sea trout, *Cynoscion nebulosus*.

Aggregated means for each species (Table 4) provide estimates of the extent of time operators targeted a species. Because of averaging, the figures provided for each species may not be representative of any particular boat. In Texas, highest mean percent targeting time was devoted to snapper, whereas in Florida it was devoted to a combination of snapper and grouper. Another indication of targeting diversity is number of species that receive ≥2% of mean percent targeting time per state or region. The northern Gulf states had 8 species that met this criteria, Florida 5, and Texas 3.

An estimate of effort units by the population of party boats revealed that the Florida fleet accounted for 74% overall (Table 5). Species with highest overall effort were, in descending order: Snapper, grouper, amberjack, and king mackerel, *Scomberomorus cavalla*. These four species accounted for 90% of the estimated effort. Party boat effort units in Texas were devoted primarily (95%) to snapper whereas in Florida the vast majority was devoted to snapper and grouper, collectively. In the northern Gulf states, effort focused on red drum and spotted sea trout; there was little effort for snapper.

Party boat operators were diverse in their views of management regulations in force. Whereas most party boat operators supported current (1987-88) regulations for red drum in the EEZ (18-inch minimum and 32-inch maximum) and king mackerel (3-fish bag limit (EEZ)), most were neutral or opposed to current red snapper regulations (13-inch minimum with incidental catch of 5 undersized fish, no bag limit (EEZ)) (Table 6). Highest levels of percent support (≥65%) among party boat operators were in Texas for red drum, spotted sea trout, and king mackerel and in Florida for king mackerel and red drum. Conversely, ≥60% of sampled party boat operators in Texas opposed red snapper regulations while ≥60% in the northern Gulf opposed red drum regulations. Species with levels of neutral response ≥30% included Spanish mackerel, *S. maculatus;* red snapper; and cobia, *Rachycentron canadum*, in the northern Gulf states and red snapper in Florida. While a majority of party boat operators in Florida supported existing regulations for each of the six species, most operators in the northern Gulf states opposed existing regulations for four of the six selected species. With the exception of red snapper, most Texas party

Table 4.—Estimated mean percent time targeting selected species by sample of party boat by state or region.

	Texas (n=12)		N. Gulf states (n=5)		Florida (n=15)	
Species	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.
Amberjack	0.9	0	0.8	0.8	7.6	2.6
Barracuda	0.0	0	0.8	0.8	0.9	0.5
Blackfin tuna	0.0	0	0.8	0.8	0.7	0.5
Blue marlin	0.0	0	0.8	0.8	0.3	0.3
Bluefin tuna	0.0	0	0.8	0.8	0.1	0.1
Bluefish	0.0	0	4.2	1.9	0.1	0.1
Bonito	0.0	0	2.7	1.8	1.2	0.7
Cobia	0.0	0	0.8	0.8	2.0	0.5
Dolphin	0.0	0	0.8	0.8	1.6	0.6
Flounder	0.0	0	0.8	0.8	3.5	1.9
Grouper	4.0	4	2.7	1.8	28.8	7.2
King mackerel	6.0	42	13.3	9.5	0.9	0.7
Ladyfish	0.0	0	0.8	0.8	1.7	1.1
Red drum	0.0	0	14.6	9.2	1.7	1.1
Sailfish	0.0	0	0.8	0.8	0.6	0.4
Shark	0.0	0	2.6	1.8	1.4	0.6
Snapper	71.0	11	0.8	0.8	38.4	8.5
Spanish mackerel	0.0	0	6.6	2.1	2.6	1.3
Spotted sea trout	0.0	0	12.3	8.5	1.6	1.1
Swordfish	0.0	0	0.8	0.8	0.4	0.3
Wahoo	0.0	0	0.8	0.8	0.3	0.2
White marlin	0.0	0	0.8	0.8	0.5	0.4
Yellowfin tuna	0.0	0	0.8	0.8	0.5	0.4

Table 5.—Estimated effort units for species targeted by party boats by state or region.

	Texas		N. Gulf states		Florida		U.S. Gulf	
Species	No.	%	No.	%	No.	%	No.	%
Amberjack	0[1]	0.0	2	0.5	281	6.2	283	4.6
Barracuda	0	0.0	2	0.5	19	0.4	21	0.3
Blackfin tuna	0	0.0	2	0.5	8	0.2	10	0.2
Blue marlin	0	0.0	2	0.5	2	0.0	4	0.1
Bluefin tuna	0	0.0	2	0.5	<1	0.0	2	0.0
Bluefish	0	0.0	30	8.3	<1	0.0	30	0.5
Bonito	0	0.0	14	3.9	35	0.7	49	0.8
Cobia	0	0.0	2	0.5	50	1.1	52	0.8
Dolphin	0	0.0	2	0.5	46	1.0	48	0.8
Flounder	0	0.0	2	0.5	59	1.3	61	1.0
Grouper	12	0.9	14	3.9	1,670	36.7	1,696	27.4
King mackerel	48	3.8	64	17.6	15	0.3	127	2.1
Ladyfish	0	0.0	2	0.5	14	0.3	16	0.3
Red drum	0	0.0	63	17.4	14	0.3	77	1.2
Sailfish	0	0.0	2	0.5	7	0.2	9	0.1
Shark	0	0.0	14	3.9	35	0.8	49	0.8
Snapper	1,207	95.2	2	0.5	2,227	48.9	3,436	55.6
Spanish mackerel	0	0.0	36	9.9	44	1.0	80	1.3
Spotted sea trout	0	0.0	98	27.0	13	0.3	111	1.8
Swordfish	0	0.0	2	0.5	3	0.1	5	0.1
Wahoo	0	0.0	2	0.5	2	0.0	4	0.1
White marlin	0	0.0	2	0.5	4	0.1	6	0.1
Yellowfin tuna	0	0.0	2	0.5	4	0.1	6	0.1
Total	1,267	99.9	363	99.4	4,553	100.0	6,182	100.0

[1]Effort units were calculated by multiplying the population of party boats in each state (Table 1) by the mean percent time targeted for each species by the sample of party boat operators in each state (Table 4).

Table 6.—Percent of sample of party boat operators supporting or opposing catch restrictions for selected species in the U.S. Gulf of Mexico by state or region.

	Texas (n=12)		N. Gulf states (n=5)		Florida (n=20)		U.S. Gulf (n=37)	
Species	%S[1]	%O[2]	%S	%O	%S	%O	%S	%O
Bluefin tuna	NA[3]		NA		50	10		
Cobia	58[4]	16	20	40	57	14	51	19
King mackerel	67	25	40	40	65	6	62	16
Red drum	75	25	40	60	65	20	65	27
Red snapper	17	67	20	40	52	14	35	35
Spanish mackerel	58	17	20	40	62	29	51	27
Spotted sea trout	67	17	60	40	NA			

[1]%S = Percent of operators supporting restrictions.
[2]%O = Percent of operators opposing restrictions.
[3]NA = Not asked.
[4]Residual percents include captains who were neutral.

boat operators supported regulations for the remaining five species.

Discussion

Results revealed why major opposition would be expected from Texas party boat operators for red snapper bag limits (e.g., 7 or 2 fish) or other restrictions proposed by the GMFMC. First, most operators in Texas indicated they were dependent on one or two species in contrast with the situation elsewhere in the Gulf. Second, the mean percent time targeting snapper in Texas was twice that of operators in Florida. Third, whereas party boat operators in Florida generate nearly twice as many snapper effort units, the vast majority of effort units in Texas is devoted to snapper. Finally, Texas operators expressed the most opposition to red snapper regulations (minimum size length of 13 inches) in force in 1987-88 or to any species regulation for that matter.

Our results provide a unique regional view of targeting behavior and estimated effort in the party boat fishery to complement party boat catch and biomass estimates by state (Goodyear and Phares, 1990). Also, our overview provides a more complete understanding of regulatory impacts on small business as required by the Regulatory Flexibility Act of 1980 (5 U.S.C. 601 et seq.). The purpose of this legislation was to promote a process whereby agencies are required "to solicit the ideas and comments of small businesses . . . to examine the impact of proposed and existing rules on such entities and to review the continued need for existing rules. Regulatory Impact Reviews (RIR's) for various amendments to the Reef Fish Fishery Management Plan (GMFMC) aggregate party boats in the U.S. Gulf of Mexico and consequently understate impacts on operators who chiefly target snapper and overstate impacts on those who don't. At a minimum, an RIR should identify 1) activity centers of party boats most dependent on a particular species, 2) where targeting time and estimated effort are the greatest (or where operators are likely to be more impacted by new regulations), 3) where current effort is concentrated on a limited number of species including the regulated species, and 4) where substitutable species are available for increased targeting. By understanding the assemblage of fish currently targeted by party boat operators in each state, it is possible to predict the likelihood that other species will become more heavily targeted in response to increased regulation of the primary target species and better assess potential economic impacts. Finally, the overview provided should give managers a better idea of where to expect opposition to new rules and a means by which a negotiated settlement can be achieved.

Because fisheries management decisions are made in the political arena as prescribed by the MFCMA, managers have a better chance of protecting and/or rebuilding fish stocks if they recognize social impacts on constituents like party boat operators. First, managers must develop more of an appreciation for the "politician" fishery management style as described by Miller and Gale (1986). Second, they need to understand that a policy, no matter how scientifically sound, will probably be rejected if not in accord with fundamental views held by the public (Vanderpool[3]). Third, managers require a more extensive understanding of the organization, attitudes and opinions of those likely to be impacted by rule making than is currently the case. This understanding can be obtained by more extensive use of personal interviews to assess human dimensions of the party boat fishery, for example, to the same extent we do measurement of catch numbers, biomass, and length frequencies. Finally, human dimensions information needs to be used in a pro-active manner to anticipate, avoid, and mitigate unacceptable social impacts.

Arguably, NMFS has a stake in the viability of the party boat fishery for social and political purposes. The party boat industry needs to survive from a social equity perspective, namely, anglers wishing to fish offshore should have the means to do so regardless of economic or class distinctions. Without party boats, many anglers without boats would be precluded or constrained from offshore fishing. If this occurs, the idea that only wealthy individuals fish offshore is perpetuated and broad-based public support for NMFS and its budget can be undermined.

There are implications for future research and extension efforts. First, before we can predict party boat fishery impacts (i.e., catch, effort, profitability, etc.) associated with alternative management actions, we need to understand how anglers will respond. Research needs to focus on angler catch rate elasticities and whether, in light of new regulations, they will continue to fish for red snapper, for example, or substitute other species. We need to know the extent to which anglers will reduce or quit fishing for a particular species and/or substitute alternative species. Second, we would hope Sea Grant marine extension programs, which have heretofore played a minor role in providing information and technical assistance to this sector in the Gulf of Mexico (Ditton et al., 1988; Holland and Milon, 1989), can help party boat operators cope with the uncertainties they face as a result of Federal rule making. In particular, operators need assistance in developing new products (i.e., fishing experiences that target alternate species in demand or promote noncatch aspects) and new clientele for their services.

Acknowledgments

This research was supported by the Gulf of Mexico Marine Fisheries Initiative (MARFIN) administered by the National Marine Fisheries Service, NOAA. Additional funding support was provided by the Texas Agriculture Experiment Station and the University of Florida, Division of Sponsored Research. We appreciate the review comments Larry McEachron and Ronald L. Schmied provided on an earlier version of this manuscript. We acknowledge the efforts of our coinvestigators John R. Stoll and J. Walter Milon, field

[3]Vanderpool, J. K. 1987. Social assessment of fisheries resources: Policy and institutional framework in the Great Lakes. Unpubl. pap. pres. at the 117th American Fisheries Society Annual Meeting, Winston-Salem, N. C., 25 p.

interviewers, and project support staff, and, most importantly, the party boat operators who answered our questions. This paper could not have been written without the information they provided voluntarily.

Literature Cited

Browder, J. A., J. C. Davis, and C. B. Austin. 1978. Study of the structure and economics of the recreational paying-passenger fisheries of the Florida Gulf Coast and Keys, from Pensacola to Key West. U.S. Dep. Commer. NOAA, Natl. Mar. Fish. Serv., NMFS Contr. 03-7-042-35142, 120 p.

Carls, E. G. 1976. Long Island boat fishermen. State Univ. N.Y. and Cornell Univ., Ithaca, Sea Grant Rep., 34 p.

Ditton, R. B., and D. A. Gill. 1988. Developing strategies to enhance charter and head boat fishing operations in Texas, Louisiana, Mississippi and Alabama. U. S. Dep. Commer., NOAA, Natl. Mar. Fish Serv., Final Rep. NMFS Contr. NA86WC-H-06107, 331 p.

————, J. R. Stoll, and D. A. Gill. 1988. The social structure and economics of the charter and party boat fishing fleets in Alabama, Mississippi, Louisiana and Texas. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Final Rep. NMFS Contr. 5617000, 323 p.

Fraser, M. B., J. A. Henderson, and J. F. McManus. 1977. Survey of commercial sportsfishing boats in the coastal United States. Oreg. State Univ. Sea Grant Coll. Program, Sea Grant Rep. ORESU-T-77-009, 12 p.

Goodyear, C. P., and P. Phares. 1990. Status of red snapper stocks of the Gulf of Mexico report for 1990. U. S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent. Rep. CRD89/90-05, 72 p.

Holland, S. M., and J. W. Milon. 1989. The structure and economics of the charter and party boat fishery fleet of the Gulf Coast of Florida. U.S. Dep. Commer, NOAA, Natl. Mar. Fish. Serv. Final Rep. NMFS Contr. NA87WC-H-06141, 278 p.

McEachron, L. W. 1984. Harvest estimates for Texas charter boats (1978-1982). Tex. Parks Wildl. Dep., Tech. Ser. Rep. 29, 90 p.

———— and G. C. Matlock. 1983. An estimate of harvest by the Texas charter boat fishery. Mar. Fish. Rev. 45(1):11-17.

Miller, M. L., and R. P. Gale. 1986. Professional styles of Federal forest and marine fisheries resource managers. N. Am. J. Fish. Manage. 6(2):141-148.

———— and J. Van Maanen. 1983. The emerging organization of fisheries in the United States. Coast. Zone Manag. J. 10:369-386.

Prochaska, F. J., and J. D. Cato. 1975. Northwest Florida Gulf Coast red snapper-grouper party boat operators—an economic analysis, 1974. Fl. Sea Grant Program, Sea Grant Rep. SUSF-SG-75-007, 9 p.

Schmied, R. L. 1975. An exploratory analysis of the Texas charter and party boat fishing industry. Tex. A&M Univ., Coll. Sta. Master prof. pap. (unpubl.).

Woods, S. A. 1977. A business analysis of the party boat industry on the Texas gulf coast. Tex. A & M Univ., Coll. Sta. Masters thesis (unpubl.).

The U.S. Gulf of Mexico Charter Boat Industry: Activity Centers, Species Targeted, and Fisheries Management Opinions

STEPHEN M. HOLLAND, ROBERT B. DITTON, and DUANE A. GILL

Introduction

In managing fish stocks, management agencies need information on the various sectors of the recreational fishing industry. Access to some nearshore and offshore fishing resources requires the use of a boat. The three major means of accessing offshore recreational fishing involve private boats, party (or head) boats, and charter boats. Because of the disaggregate nature of the marine recreational fishing industry, understanding the total picture is difficult (Dubose and Radonski, 1984). Partitioning the industry offers a better approach to collecting data required by managers in support of decision making.

Stephen M. Holland is with the Department of Recreation, Parks and Tourism, University of Florida, Gainesville, FL 32611. Robert B. Ditton is with the Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843. Duane A. Gill is with the Department of Sociology/Anthropology and Social Science Research Center, Mississippi State University, Mississippi State, MS 39762. Views or opinions expressed or implied are those of the authors and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA.

ABSTRACT—The charter boat industry in U.S. Gulf of Mexico provides access to offshore fishing opportunities for about 570,000 passengers per year on 971 boats. A 25% random sample of charter boat operators was interviewed during 1987-88 to determine species targeted, percent time committed to targeting each species, and reactions to existing catch restrictions. Three-fourths of the charter boat fleet was in Florida, 13% in Texas, 5% in Louisiana, 4% in Alabama, and 2% in Mississippi. Responses were diverse regarding species focus within the region. Species of dominant importance included groupers, Epinephelus *sp. and* Mycteroperca sp. *(Fla.); snapper,* Lutjanus campechanus *(Ala., Fla., Miss., and La.); king mackerel,* Scomberomorus cavalla *(Miss., Tex., Ala. and Fla.); spotted seatrout,* Cynoscion nebulosus *(Tex. and La.); and red drum,* Sciaenops ocellatus *(Tex. and La). Catch restrictions were generally supported with higher levels of opposition to restricted high effort fish and/or one fish or closed fishery limits.*

Recent regulatory notices define a charter boat as "a vessel whose operator is licensed by the U.S. Coast Guard to carry paying passengers and whose passengers fish for a fee" (54 FR 29564). Most charter boats charge a group rate (generally >$300 for 6 passengers but sometimes offer a lower price for 3 or 4), restrict their carrying capacity to 6 passengers plus 2 crew members, and operate only when chartered by a person or group. Charter boat businesses are found in coastal areas adjacent to tourism destinations, major urban areas, and commercial fishing ports (Fraser et al., 1977). Charter boats generally solicit public business for offshore fishing trips. Charter boats operating in the Gulf of Mexico average in size from 26 feet in Texas to 42 feet in Alabama (Ditton et al., 1988; Holland and Milon, 1989). Most boats have twin engines with horsepower ratings ranging from 100 to 500.

Stock assessments reveal that many fish populations have declined dramatically as have numbers and sizes of fish caught (Bohnsack, 1989; Goodyear, 1988; Ralston, 1987; Russ and Alcala, 1989). Saltwater anglers, including those using charter boats, participated in a virtually unregulated recreational fishery prior to the 1980's (Ditton, et al., 1992). The classic tragedy of a common property resource (Hardin, 1968; Swanson et al., 1978) unfolded with dramatic increases in commercial and recreational harvest, electronic fish finders that enhance fish targeting capabilities, and an increasing number of anglers (Loomis and Ditton, 1988; Snepenger and Ditton, 1985).

In response, the Gulf of Mexico Fishery Management Council, for example, adopted fishery management plans (FMP) for reef fish (50 CFR 641), mackerels (50 CFR 642), red drum (50 CFR 653), and Atlantic billfishes (50 CFR 644) to regulate commercial and recreational fisheries including charter boat operators and customers. Fishery management councils make decisions based on their understanding of how fishing pressure will be modified and how potential regulations will impact each fishing sector. FMP's are required to provide "a description of the fishery, including, but not limited to, the number of vessels involved . . . the species of fish involved and their location, the costs likely to be incurred in management . . . any recreational interests in the fishery . . . [and] areas in which fishing was engaged in . . ." (16 U.S.C. 1853a). This information was not available when some regulations were promulgated.

An example of fisheries management actions affecting charter boats is the FMP and amendments for coastal migratory pelagics (50 CFR 642) impacting king mackerel, *Scomberomorus cavalla*, fishing. Before 1985, there were no limits on king mackerel in Fed-

eral waters. On 22 Sept. 1985, Gulf charter boat operators were restricted to a possession limit of 3 king mackerel per person per trip, excluding captain and crew or 2 king mackerels per person per trip including captain and crew, whichever is the greater (50 FR 34840). On 24 Aug. 1987, all charter boat operators targeting king mackerel were required to register with the National Marine Fisheries Service (NMFS) and obtain a king mackerel permit to target and retain this species. From 16 Dec. 1987 through 30 June 1988; 17 Dec. 1988 through 30 June 1989; 21 May 1990 through 30 June 1990; and 20 Dec. 1990 to 30 June 1991, NMFS implemented a zero bag limit prohibiting retention as recreational allocations were achieved. In addition, beginning July 1989 (54 FR 29564), selected charter boats were required to maintain daily fishing records and submit them weekly.

Harvest restrictions have the potential to impact charter boat businesses because of relatively high charter fees and their impact on angler expectations of catching fish. Charter boat businesses have nourished expectation for years with advertisements emphasizing catch. In a survey of 321 charter boat anglers, about half said "to catch a lot of fish" was at least a moderately important reason for taking their trip (Holland, 1988). "Wanting to catch a particular fish" was another important motivation for 64 percent of the anglers.

Fisheries regulations have been partially responsible for charter business failures (Ditton and Loomis, 1985; Ditton and Vize, 1987). Restrictions now exist on Spanish mackerel, *Scomberomorus maculatus*; red snapper, *Lutjanus campechanus*; grouper, *Epinephelus* sp. and *Mycteroperca* sp.; amberjack, *Seriola dumerili;* cobia, *Rachycentron canadum;* and red drum, *Sciaenops ocellatus*. Also, states have enacted regulations to restrict harvest in their waters (Gissendanner, 1982; Matlock, 1982). Discussions are continuing regarding the need for additional restrictions and closures to prevent overfishing and rebuild stocks (NMFS, 1990). In the face of proliferating fishing regulations in the Gulf, the main responses available to charter operators are to quit the charter business, resist current and new fishing regulations, and/or target other species. However, few offshore species have escaped regulation.

Managers need to know when and where charter boat fishing occurs so they can estimate potential economic and social impacts of fishery management rules. Charter boats are not only an important segment of the marine recreational fishing industry but an important component of the tourism economy in some communities (Manfredo et al., 1988; Roehl et al., 1989). Areas such as Islamorada, Panama City Beach, Destin, Orange Beach, South Padre Island, and Port Aransas receive significant direct and indirect economic impacts from fishing. Information on the regional distribution and numbers of charter boats would enhance understanding of the role of charter boats in tourism.

Previous research on charter boats has focused primarily on local economic impacts (Bell et al., 1982; Prochaska and Morris, 1977; Samples et al., 1984; Taylor et al., 1982). Other studies have focused primarily on catch data from specific areas (Brusher and Palko, 1985; Brusher et al., 1984; McEachron and Matlock, 1983). There have been a series of studies with a statewide focus but these are geographically and temporally scattered making comparisons and conclusions inconsistent (Ditton et al., 1978; Etzold et al., 1977; Falk et al., 1983; Lichtkoppler et al., 1987; Marshall and Lucy, 1981). Browder et al. (1978) published a more detailed picture of the charter boat industry, but it was limited to the Gulf coast of Florida. They studied charter boat activity centers, social and economic characteristics of operators, and the species targeted by season. This approach was partially replicated by Ditton et al. (1988) and Holland and Milon (1989) to portray charter boat characteristics and actions in the U.S. Gulf of Mexico. The data presented in this paper were taken from these two studies.

In 1985, the Gulf States Marine Fisheries Initiative program (MARFIN) was created to enhance the quantity and quality of available data on recreational and commercial fishing in the Gulf. Christmas et al. (1985) noted the following research needs: 1) "it is imperative to improve the marine recreational fisheries data base"; 2) "much of the information needed...to access the nature and impact of recreational fishing on these resources does not exist"; 3) "This situation is hindering and, in some cases, preventing the optimum use of the Gulf's fishing resources"; 4) "Accurate information on...recreational Charter and Party boats in the Gulf region ...does not exist or is not readily available even though such information would be a valuable tool for management purposes."

Because of inadequate knowledge of the industry, the importance of total economic and resource impacts and the need to understand the effect of increasing fishery management regulations, a Gulfwide study of the charter boat industry was undertaken in 1986. This paper describes the size and distribution of the charter fleet in the U.S. Gulf of Mexico, species targeted by state, estimated fishing pressure, and operator opinions on current regulations for select species.

Methods

Whereas the population of charter boats is constantly changing, estimates placed the number in the U.S. Gulf at between 800 and 1,000. The sampling frame was derived from the 1985 and 1986 charter boat lists maintained by the NMFS Southeast Fisheries Center, an inventory of charter boats maintained by the NMFS Southeast Regional Office and Panama City Laboratory, and on-site information provided by charter operators, NMFS, and project personnel. The final sample frame listed 971 boats. Charter boats were stratified by activity centers and randomly sampled. Letters or phone calls were used to contact operators to explain the intent of the survey and encourage participation. Sample sizes varied with the boat population in each state ranging from a 25 percent sample of the 736 charter boats in Florida to 66 percent of the 18 charter boats in Mississippi.

A 19-page interview schedule was developed to collect information on the operator's background and demographics, boat description, species information, operating policy, boat operation, business structure, community ties, and opinions on current regulations. The interview schedule was pretested and revisions made as a result of the pretest. In this paper, we focus on data concerning species targeted, percent time committed to targeting each species, and attitudes toward current catch restrictions on select species. First, for each boat sampled, operators were given a list of 23 species and asked to indicate which were targeted during each of the previous 12 months. Second, they were asked "what percent of your fishing time was devoted to targeting each of these species" during each of four 3-month periods. Percent time targeting selected species for each 3-month-period was additive to 100%. Finally, using a 5-point balanced Likert-type scale, operators were asked if they supported or opposed current recreational catch restrictions on six species.

Charter boat operators in Texas, Mississippi, and Alabama were interviewed by trained field personnel during May through August 1987. Operators in Florida were interviewed during February through July 1988. Each interview took 30-40 minutes per boat. In some cases, prior-contacted operators were unavailable and alternative captains were substituted. Interviews were completed with 145 of 736 charter boats in Florida, 19 of 38 in Alabama, 10 of 21 in Mississippi, 21 of 48 in Louisiana, and 50 of 128 in Texas. The overall final sample was 25% of the known population of charter boats.

Results

Three-fourths of the charter boats were located in Florida, 13% in Texas, and 11% in the northern Gulf states (Table 1; Fig. 1). Major activity centers in Florida were Key West, Islamorada, Naples, Ft. Myers Beach, Boca Grande, Clearwater, Panama City/Panama City Beach, Destin, and Pensacola. The three highest concentrations of charter boats were Destin, the Panama City/Panama City Beach area, and Islamorada. Major activity centers in the other four states included Orange Beach (Alabama), Grand Isle-Chauvin-Cocodrie-Houma (Louisiana), Port Aransas (Texas), and South Padre Island-Port Isabel (Texas).

Table 1.—Distribution of population of charter boats in the U.S. Gulf of Mexico by state and area.

State and area	Population No.	Population Percent
Texas		
1. Port Isabel-Port Aransas	90	
2. Rockport-Port Arthur	38	
Subtotal	128	13.2%
Northern Gulf states		
3. Louisiana	48	4.9
4. Mississippi	21	2.2
5. Alabama	38	3.9
Florida		
6. Panhandle	198	
7. West Peninsula	332	
8. Keys	206	
Subtotal	736	75.8
Grand total	971	100.0

By extrapolation, we estimated that charter boats made 142,000 trips/year and carried about 568,000 passengers during the previous 12 months. State extrapolations estimated 118,202 trips and 472,897 passengers for Florida; 12,813 trips and 51,252 passengers for Texas; 5,011 trips and 20,045 passengers for Louisiana; 3,975 trips and 15,900 passengers for Alabama; and 1,924 trips and 7,695 passengers for Louisiana. The mean number of trips per year was fairly consistent ranging from 93 in Mississippi to 128 in Florida with a weighted Gulfwide mean of 122 charter trips per year. Gulfwide, 63% of the trips were full-day trips and 33% of the passengers went between April

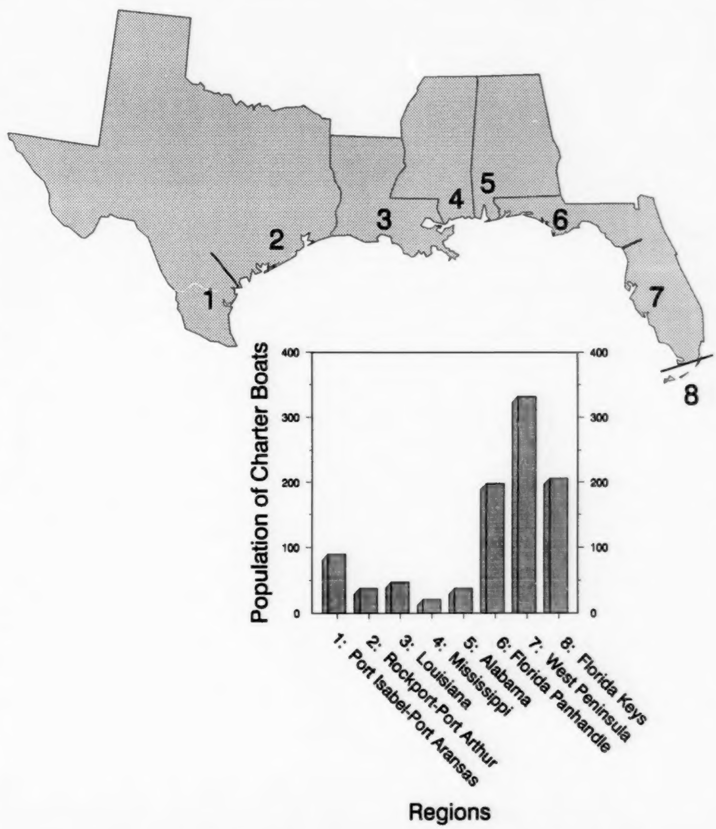

Figure 1.—Regional distribution of charter boats in the U.S. Gulf of Mexico.

and June, the heaviest season. A full 83% of the passengers utilized boats docked in Florida. Assuming 90% of the passengers fished for 5 hours of fishing/full day trip and 2.5 hours/half day trip, an estimated total of 2,085,000 hours of fishing was attributable to 511,000 anglers on charter boats annually.

The degree of species dependency varied across the region (Table 2). Most notable is the contrast between charter boats in Texas, Louisiana, and Alabama where 79%, 63%, and 47% of the boats, respectively, targeted <4 species, compared with Mississippi and Florida boats where 0 and 9%, respectively, targeted <4 species. In Mississippi, 50% of the boats targeted ≥8 species, while 56% targeted ≥8 species in Florida.

The species targeted by most (>500) boats include king mackerel, snapper, groupers, dolphin, *Coryphaena hippurus*; shark, *Carcharhinus* sp., and cobia (Table 3). Species sought by >350 but <500 boats included spanish mackerel; wahoo, *Acanthocybium solanderi*; sailfish, *Istiophorus platypterus*; blue marlin, *Makaira nigricans*; great barracuda, *Sphyraena barracuda*; blackfin tuna, *Thunnus atlanticus*; and white marlin, *Tetrapterus albidus*. Spotted seatrout, *Cynoscion nebulosus*, and red drum were relatively important to charter boat operators in Texas and Louisiana but only targeted by about 15 percent of the operators in Florida. Species targeted by most Florida operators included grouper, king mackerel, snapper, amberjack, dolphin, bonito, *Sarda sarda;* and shark. Since operators targeted several species, columns in Table 3 are not additive and hence percents would be meaningless.

Estimates of mean percent time spent targeting each species by charter operators quantified the degree of variability across the region (Table 4). Each state has a few species that dominate targeting time such as spotted seatrout in Texas and Louisiana with red drum and snapper also strong; king and spanish mackerel in Mississippi; snapper and king mackerel in Alabama; and grouper, snapper, dolphin, and king mackerel in Florida. The table lists aggregate means for each state's sample of boats, and consequently reported averages may not reflect the individual actions of any one boat. Another indication of the extent of targeting diversity is the number of species receiving ≥2 percent of mean targeting time/state. Texas and Louisiana have 5 species that meet this criteria, Alabama, 8; Mississippi, 13; and Florida, 15.

An estimate of effort units by the population of charter boats revealed the Florida fleet dominated with 84% overall (Table 5). Species with the highest overall effort were (in descending order): Grouper, snapper, king mackerel, dolphin, amberjack, and spotted seatrout. These 6 species accounted for most (68%) of the estimated effort. Grouper, snapper, and amberjack received most of the effort in the Panhandle and Peninsula sections of Florida, king mackerel in the Panhandle and Keys of Florida, dolphin in the Florida Keys (and relatively little in the rest of the state), and spotted seatrout and red drum in Texas and Louisiana. Snapper was the dominant species in Alabama, and king mackerel, Spanish mackerel, and snapper received most of the effort by Mississippi operators.

As a final indication of orientation toward selected species, operators were asked to express opposition or support for current catch restrictions. At the time of the data collection, the following restrictions (Federal EEZ limits unless otherwise noted) were in place relative to charter fishing operations: King mackerel, three fish bag limit excluding captain and crew; Spanish mackerel, 12-inch fork length minimum size and four-fish bag limit; red snapper, 12-inch fork length minimum size limit with a five undersize fish tolerance and various state size and bag limits; cobia, 33-inch fork length minimum size; red drum, a one-fish EEZ bag limit existed which was reduced to zero on 1 Jan. 1988 and, at the state level, various size limits, bag limits, and closed seasons existed; spotted seatrout, no EEZ limits existed but various size and bag limits were operable at the state levels; bluefin tuna, annual retention of one bluefin greater than 77 inches fork

Table 3.—Number of charter boats operating from Texas, Louisiana, Mississippi, Alabama (1986-87), Florida (1987-88), and the U.S. Gulf of Mexico by species targeted.

	Number of charter boats					
Species	Tex.	La.	Miss.	Ala.	Fla.	U.S. Gulf
Amberjack	5	6	4	15	539	569
Barracuda	5	2	2	2	371	382
Blackfin tuna	5	6	0	3	365	379
Blue marlin	9	2	0	2	388	401
Bluefin tuna	5	0	2	0	87	94
Bluefish	0	2	8	5	249	264
Bonito	9	0	8	7	481	505
Cobia	7	15	10	12	458	502
Dolphin	16	9	8	7	504	544
Flounder	5	0	0	2	156	163
Grouper	9	2	8	15	597	631
King mackerel	47	13	14	25	597	696
Ladyfish	2	0	2	3	191	198
Red drum	58	34	10	10	110	222
Sailfish	9	2	2	3	394	410
Shark	12	4	10	3	481	510
Snapper	26	21	8	32	562	649
Spanish mackerel	2	0	12	13	435	462
Spotted seatrout	65	32	4	3	99	203
Swordfish	2	0	2	2	116	122
Wahoo	5	2	2	3	411	423
White marlin	7	2	2	3	359	373
Yellowfin tuna	5	2	2	2	232	243

Table 2.—Distribution of number of species targeted by the number of charter boats in the U.S. Gulf of Mexico during a 1-year period by state.

No. of species targeted	Tex.		La.		Miss.		Ala.		Fla.		U.S. Gulf	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	18	13.8	5	10.4	0	0.0	4	10.5	17	2.3	44	4.5
2	36	27.8	14	29.2	0	0.0	4	10.5	29	3.9	83	8.5
3	49	37.8	11	22.9	0	0.0	6	15.8	23	3.1	89	9.2
4	5	3.8	5	10.4	2	10.0	4	10.5	23	3.1	39	4.0
5	5	3.8	2	4.2	2	10.0	4	10.5	52	7.1	65	6.7
6	5	3.8	0	0.0	2	10.0	4	10.5	46	6.3	57	5.9
7	3	2.3	0	0.0	4	20.0	4	10.5	41	5.5	52	5.4
8	3	2.3	0	0.0	2	10.0	0	0.0	23	3.1	28	2.9
9	3	2.3	9	18.7	0	0.0	2	5.3	35	4.7	49	5.0
10	0	0.0	2	4.2	2	10.0	0	0.0	41	5.5	45	4.6
>10	3	2.3	0	0.0	6	30.0	6	15.8	406	55.1	421	43.3
Totals	130[1]	100.0	48	100.0	20	100.0	38	99.9	736	100.0	972	100.0

[1]Because No.'s are extrapolated, there is some rounding error which accounts for slight deviations from state total No. reported in other tables.

Table 4.—Estimated mean percent time targeting selected species by charter boat operators in Texas, Louisiana, Mississippi, Alabama and Florida.

	Texas (n=48)		Louisiana (n=21)		Mississippi (n=9)		Alabama (n=21)		Florida (n=128)	
Species	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.
Amberjack	0.5	0.3	0.8	0.5	0.9	0.8	5.5	2.1	7.7	0.9
Barracuda	0.3	0.3	0.0	0.0	0.8	0.8	0.2	0.2	3.3	0.7
Blackfin tuna	0.2	0.1	0.3	0.2	0.0	0.0	0.3	0.2	2.1	0.4
Blue marlin	1.4	0.8	0.0	0.0	0.0	0.0	0.2	0.2	2.8	0.6
Bluefin tuna	0.2	0.2	0.0	0.0	1.4	1.4	0.0	0.0	0.2	0.1
Bluefish	0.0	0.0	0.1	0.1	3.4	1.8	0.6	0.4	0.9	0.2
Bonito	0.8	0.5	0.0	0.0	2.0	1.1	1.2	0.7	3.8	0.9
Cobia	0.5	0.4	2.4	1.0	3.3	1.3	2.4	1.1	3.1	0.6
Dolphin	1.1	0.6	1.2	0.7	2.0	1.2	0.8	0.4	9.9	1.4
Flounder	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.8	0.2
Grouper	2.0	0.7	0.0	0.0	2.2	1.2	5.0	1.7	15.6	1.8
King mackerel	11.3	2.6	3.4	1.4	11.3	4.4	12.1	3.3	9.3	1.2
Ladyfish	0.0	0.0	0.0	0.0	2.5	1.7	0.5	0.4	0.7	0.2
Red drum	17.3	3.0	14.0	3.5	6.2	2.9	2.2	1.2	1.4	0.5
Sailfish	0.8	0.5	0.0	0.0	2.8	2.8	0.5	0.3	6.8	1.1
Shark	0.4	0.2	1.0	0.9	3.7	1.7	0.5	0.4	5.6	1.1
Snapper	9.6	3.3	14.9	4.3	6.8	4.8	45.7	7.5	12.2	1.3
Spanish mackerel	0.2	0.2	0.0	0.0	10.3	4.7	2.7	1.0	3.7	0.6
Spotted seatrout	32.7	4.9	42.0	7.9	3.8	2.9	5.0	4.6	2.6	0.8
Swordfish	0.1	0.1	0.0	0.0	1.4	1.4	0.2	0.2	0.3	0.1
Wahoo	0.6	0.5	0.0	0.0	0.9	0.9	0.3	0.2	2.6	0.5
White marlin	1.1	0.8	0.0	0.0	2.8	2.8	0.5	0.3	2.4	0.7
Yellowfin tuna	0.2	0.2	0.0	0.0	1.4	1.4	0.2	0.2	0.7	0.2

length with no limits on smaller fish.

The majority of operators supported fishery regulations except in the case of closures or one-fish limits. There was 60% support for catch restrictions overall with a 78% support level for cobia minimum size limits (Table 6). There were greater levels of support in Mississippi and Alabama for all 6 species. Most opposition was in Texas and Alabama for red snapper minimum size and possession limits, Louisiana for the red drum one-fish limit, and Florida for king and Spanish mackerel and red drum regulations. The relatively high opposition to king and Spanish mackerel restrictions in Florida was probably a reaction to the closure of the recreational fishery for these two species between 16 Dec. 1987 and 30 June 1988 when the recreational allocation had been reached. Because of migratory pattern for these species, this closure affected Florida operators more than those in other States. Red drum opposition also reflected a total closure in effect for several months as well as the one-fish bag limit for Louisiana anglers.

Discussion

It appears there has been overall evenhandedness in controlling harvest throughout the U.S Gulf of Mexico. However, red drum limits have had a greater impact on Mississippi, Louisiana, and Texas operators, and mackerel closures have more seriously affected some Florida operators. Florida charter boats target the widest variety of species (50% of Florida operators fish for ≥12 species) with 77% of the effort focused on 7 species. These operators have more flexibility than those in other areas in targeting substitutes for restricted species. The Alabama and Mississippi charter boat operators are less varied. Notably, 79% of Alabama operators and 50% of Mississippi operators target ≤7 species. More specifically, 86% of the Alabama effort focused on two species, and 75% of the Mississippi effort focused on five species. In the western Gulf (Louisiana and Texas), targeting is concentrated with 63% of Louisiana operators and 79% of Texas operators targeting ≤3 species with 95% of Louisiana effort and 91% of Texas effort focused on three species. The inability of operators in some regions to substitute alternative species could lead to increased business failures.

In designing an allocation scheme, FMP's should consider factors such as economic and social consequences and dependence on the fishery by present participants and coastal communities (50 CFR 602.14 sect. c, iv). The Magnuson Fishery Conservation and Management Act of 1976 (16 USC 1801-1882), section 1851a4 states "Conservation and management measures shall not discriminate between residents of different states. If . . .

Table 5.—Estimated effort units for species targeted by charter boats by state and region.

	Texas		Louisiana		Mississippi		Alabama		Florida		U.S. Gulf	
Species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Amberjack	2[1]	0.1	5	0.2	4	0.6	82	4.0	4,150	8.8	4,243	7.5
Barracuda	2	0.1	0	0.0	2	0.3	<1	0.0	1,224	2.6	1,229	2.2
Blackfin tuna	1	0.0	2	0.1	0	0.5	1	0.1	767	1.6	771	1.4
Blue marlin	13	0.3	0	0.0	0	0.0	<1	0.0	1,086	2.3	1,100	1.9
Bluefin tuna	1	0.0	0	0.0	3	0.5	0	0.0	17	0.1	21	<0.1
Bluefish	0	0.0	<1	0.0	27	4.3	3	0.1	224	0.5	255	0.5
Bonito	7	0.2	0	0.0	16	2.5	8	0.4	1,828	3.9	1,859	3.3
Cobia	4	0.1	36	2.0	33	5.2	29	1.4	1,420	3.0	1,522	2.7
Dolphin	18	0.5	11	0.5	16	2.5	6	0.3	4,990	10.5	5,041	9.0
Flounder	0	0.0	0	0.0	0	0.0	<1	0.0	125	0.3	126	0.2
Grouper	18	0.5	0	0.0	18	2.9	75	3.7	9,313	19.7	9,424	16.8
King mackerel	531	13.3	44	2.0	158	25.0	303	15.0	5,552	11.8	6,588	11.7
Ladyfish	0	0.0	0	0.0	5	0.8	2	0.1	134	0.3	141	0.3
Red drum	1,003	25.0	476	21.0	62	9.8	22	1.0	154	0.3	1,717	3.0
Sailfish	7	0.2	0	0.0	6	1.0	2	0.1	2,679	5.7	2,694	4.8
Shark	5	0.1	4	0.2	37	5.9	2	0.1	2,694	5.7	2,742	4.9
Snapper	249	6.2	312	14.0	90	14.3	1,462	71.0	6,856	14.5	8,969	16.0
Spanish mackerel	<1	0.0	0	0.0	124	19.7	35	1.7	1,610	3.4	1,770	3.2
Spotted seatrout	2,126	53.1	1,344	60.0	15	2.4	15	0.7	257	0.5	3,757	6.7
Swordfish	<1	0.0	0	0.0	3	0.5	<1	0.0	35	<0.1	40	0.1
Wahoo	3	0.1	0	0.0	2	0.3	1	0.1	1,069	2.3	1,075	1.9
White marlin	8	0.2	0	0.0	6	1.0	2	0.1	862	1.8	878	1.5
Yellowfin tuna	1	0.0	0	0.0	3	0.5	<1	0.0	162	0.3	167	0.3
Total	3,999	100.0	2,234	100.0	630	100.0	2,050	100.0	47,208	100.0	56,129	100.0

[1]Effort units were calculated by multiplying the population of charter boats in each state (Table 1) by the mean percent time targeted for each species by the sample of charter boat captains in each state (Table 4).

Table 6.—Percent of charter boat operators supporting or opposing catch restrictions for selected species in the U.S. Gulf of Mexico by state.

Species	Texas (n=49)		La. (n=19)		Miss. (n=9)		Alabama (n=19)		Florida (n=132)		U.S. Gulf (n=228)	
	%S[1]	%O[2]	%S	%O	%S	%O	%S	%O	%S	%O	%S	%O
Bluefin tuna	NA[3]		NA		NA		NA		50	11		
Cobia	67	7	66	22	78	11	84	0	70	14	78	14
King mackerel	72[4]	11	74	5	89	11	95	5	47	47	62	33
Red drum	88	8	75	25	89	11	84	11	47	25	61	21
Red snapper	49	18	58	11	88	0	79	21	61	14	65	12
Spanish mackerel	68	5	53	5	75	13	90	10	55	31	59	21
Spotted seatrout	79	14	75	20	100	0	69	5	NA			

[1]%S = Percent of operators supporting restrictions.
[2]%O = Percent of operators opposing restrictions.
[3]NA = Not asked.
[4]Residual percents are captains who were neutral.

necessary . . . allocation shall be fair and equitable to all such fishermen. . . and carried out in such a manner that no particular individual, corporation or other entity acquires an excessive share of such privileges." Section 1851a6 goes on to say: "Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishing resources, and catches." The data reported in this study establish a perspective from which decisions on these issues can begin to be made.

Each species-specific catch restriction will likely have differential impacts due to regional differences in species preference or dependence. Snapper dominates targeting in Alabama; king mackerel, Spanish mackerel, and snapper are the focus in Mississippi; spotted seatrout, red drum, and snapper are the primary targets in Louisiana, and spotted seatrout, red drum, and king mackerel are the dominant species in Texas. This information can be used to understand why opposition to existing and proposed management actions varies from one area to another.

Although the scope of charter fishing in the Gulf of Mexico is substantial (particularly in Florida), it is secondary to private boats. Estimates for the five Gulf states indicate that 44% of saltwater anglers fished from private boats and 23% from charter/party boats (USFWS, 1988, 1989). The National Marine Fisheries Service (NMFS, 1986) Marine Recreational Fishery Statistics Survey estimated the proportion of all trips in the U.S. Gulf of Mexico by private boats was 48% and 7% for charter/party boats. About 68% of the total number of fish caught was taken by anglers in private boats. Regulatory measures may be more effective with private boat owners since they account for a larger proportion of harvest. Also, private boat owners have greater latitude in coping with new regulations and their impacts than charter boat operators. Private boat operators do not have to "justify" a $400 fee with a sizeable catch, nor do they need to earn a living through fishing.

The economic benefits to charter operators and community businesses (hotels, restaurants, gas stations, bait shops, ice distributors, etc.) are substantial. By extrapolating expenditures per angler from a survey of 315 charter boat customers (Holland, 1988), we estimated $146 million in total direct expenditures by charter boat anglers in the U.S. Gulf of Mexico. Hiring a charter boat for a day of deep-sea fishing offers a desired vacation option, especially for inland residents. For most anglers, charter/party boat fishing is their only opportunity to experience offshore fishing or to access certain offshore gamefish. Although most highly developed in Florida, deep-sea fishing promotion is being increasingly developed as a tourist attraction in other Gulf states.

This paper provides baseline information on the current distribution of charter businesses in the U.S. Gulf of Mexico and their species targeting focus. The level of support for fishing regulations reported by operators indicates they understand the threatened condition of the resource. Further, they appear willing to support and abide by regulations, but report higher opposition to species closures and one or two fish bag limits for high-focus species. However, given the dynamics of stock deterioration and recovery, changes are likely in the charter boat industry. This study should be replicated over time to provide trend information regarding target species, effort, and attitudes regarding current and proposed regulations. This could provide a source of empirical information on how charter fishing businesses and anglers are likely to react to changing fisheries regulations in different areas of the Gulf. However, these data do not allow us to quantitatively predict the economic impact that proposed or existing regulations will have or are having on charter businesses and coastal economies. To determine this, we need a more definitive understanding of angler catch rate elasticities for species or species complexes. We need to know more about angler willingness and ability to substitute other species as targets. Understanding variations in angler satisfaction levels with reduced retention of targeted species must also be improved. These topics deserve priority in future research initiatives.

Acknowledgments

This research was supported by the Gulf of Mexico Marine Fisheries Initiative (MARFIN) administered by the National Marine Fisheries Service, NOAA. Additional funding support was provided by the Texas Agriculture Experiment Station and the University of Florida, Division of Sponsored Research. We appreciate the review comments of Robert G. Muller and Ronald L. Schmied. Also, we acknowledge the efforts of our coinvestigators John R. Stoll and J. Walter Milon, field interviewers and project support staff, and, most importantly, the charter boat operators who voluntarily answered our questions.

Literature Cited

Bell, F. W., P. E. Sorensen, and V. R. Leeworthy. 1982. The economic impact and valuation of saltwater recreational fisheries in Florida. Fla. Sea Grant Coll. Program, Sea Grant Rep. SGR-47, 118 p.

Bohnsack, J. A. 1989. The impact of overfishing on tropical fisheries. *In* J. DeGraaf and D. R. Moore (Editors), Proceedings of the conference on fisheries in crises, p. 35-49. Gov. Virgin Isl., Dep. Plan. Nat. Res., Charlotte Amalie.

Browder, J. A., J. C. Davis, and B. C. Austin. 1978. Study of the structure and economics of the recreational paying-passenger fisheries of the Florida Gulf coast and keys, from Pensacola to Key West. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Final Rep., Contr. 03-7-042-35142, 120 p.

Brusher, H. A., M. L. Williams, L. Trent, and B. J. Palko. 1984. Using charterboat catch records for fisheries management. Mar. Fish. Rev. 46(3):48-55.

———— and B. J. Palko. 1985. Charterboat catch and effort from southeastern U.S. waters, 1983. Mar. Fish. Rev. 47(3):54-66.

Christmas, J. Y., D. J. Etzold, T.D. McIlwain, and L. B. Simpson. 1985. Marine Fisheries Initiative: Gulf of Mexico phase. Gulf States Mar. Fish. Comm., Publ. 10, 144 p.

Ditton, R. B., R. N. Jarman, and S. A. Woods. 1978. An analysis of the charter boat fishing industry on the Texas Gulf coast. Mar. Fish. Rev. 40(8):1-7.

———— and D. K. Loomis. 1985. Examining business turnover in the Texas charter boat industry: 1975-1980. Mar. Fish. Rev. 47(1):43-47.

———— and J. D. Vize. 1987. Business turnover in the Texas charter fishing industry, 1975-85. Mar. Fish. Rev. 49(2):162-165.

————, J. R. Stoll, and D. A. Gill. 1988. The social structure and economics of the charter and party boat fishing fleets in Alabama, Mississippi, Louisiana and Texas. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Final Rep. Contr. 5617000, 323 p.

————, A. J. Fedler, and R. Christian. 1992. The evolution of recreational fisheries management in Texas. J. Ocean Shoreline Manage. 17:169–181.

Dubose, W. P, and G. C. Radonski. 1984. Problems confronting the marine recreational fishing industry. *In* R. H. Stroud (Editor), Marine recreational fisheries 9, p. 53-63. Natl. Coalition Marine Conserv., Savannah, Ga.

Etzold, D. J., N. O. Murray, and D. V. Veal. 1977. Charter boat fishing on the Mississippi Gulf coast. Miss.-Ala. Sea Grant Coll. Program, Sea Grant Rep. MASGP-77-021, 15 p.

Falk, J. M., A. R. Graefe, C. Alkire, and D. Swartz. 1983. 1982 head/charter-boat fishing in Delaware: An analysis of customers and their economic impact. Del. Sea Grant Coll. Program, Sea Grant Rep. DEL-SG-03-83, 54 p.

Fraser, M. B., J. A. Henderson, and J. F. McManus. 1977. Survey of commercial sportfishing boats in the coastal United States. Oreg. State Univ. Sea Grant Coll. Program, Sea Grant Rep. ORESU-T-77-009, 12 p.

Gissendanner, E. J. 1982. Controversies and conflicts in Florida's marine recreational fisheries. *In* R.H. Stroud (Editor), Marine recreational fisheries 7, p. 81-99. Sport Fish. Inst., Wash., D.C.

Goodyear, C. P. 1988. Recent trends in the red snapper fishery of the Gulf of Mexico. U.S. Dep. Commer., NOAA, Southeast Fish. Centr., CRD 87/88-16, 125 p.

Hardin, G. 1968. The tragedy of the commons. Science 162:1243-1248.

Holland, S. M. 1988. Charter and headboat fishing as a sector of the tourism industry in Florida: Guidelines for greater integration and improved economic vitality. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Final Rep. Contr. NA86WC-H-06107, 279 p.

———— and J. W. Milon. 1989. The structure and economics of the charter and party boat fishing fleet of the Gulf coast of Florida. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Final Rep. Contr. NA87WC-H-06141, 278 p.

Lichtkoppler, F. R., L. J. Hushak, O. David, and F. L. Snyder. 1987. The 1985 Ohio charter captains survey. Fisheries 12(4):14-18.

Loomis, D. K., and R. D. Ditton. 1988. Technique for projecting the future growth and distribution of marine recreational fishing demand. N. Am. J. Fish. Manage. 8:259-263.

Manfredo, M. J., M. Lee, and K. Ford. 1988. Alternative markets for charterboat operators affected by declining salmon allocations in Oregon. Coast. Manage. 16:215-227.

Marshall, A. R., and J. A. Lucy. 1981. Virginia's charter and headboat industry: Analysis of catch and socioeconomic impacts. Va. Sea Grant Program, Va. Inst. Mar. Sci., Gloucester Point, 90 p.

Matlock, G. C. 1982. The conflict between user groups of red drum and spotted seatrout in Texas. *In* R.H. Stroud (Editor), Marine recreational fisheries 7, p. 101-108. Sport Fish. Inst., Wash., D.C.

McEachron, L. W., and G. C. Matlock 1983. An estimate of harvest by the Texas charter boat industry. Mar. Fish. Rev. 45(1):11-17.

NMFS. 1986. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1985. U.S. Dep. Commer., NOAA, Natl. Mar. Fish Serv., Curr. Fish. Stat. No. 8392, 130 p.

————. 1990. The potential of marine fishery reserves for reef fish management in the U.S. southern Atlantic. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish Cent., Tech. Memo. NMFS-SEFC-261, 45 p.

Prochaska, F. J., and R. A. Morris. 1977. Primary economic impact of the Florida commercial fishing sector. Fla. Sea Grant Coll. Program, Sea Grant Rep. SGR-25, 56 p.

Ralston, S. 1987. Mortality rates of snappers and groupers. *In* J. J. Polovina and S. Ralston (Editors), Tropical snappers and groupers: Biology and fisheries management, p. 375-404. Westview Press, Boulder, Colo.

Roehl, W. S., R. B. Ditton, and D. R. Fesenmaier. 1989. Community-tourism ties. Ann. Tour. Res. 16:504-513.

Russ, G. R., and A. C. Alcala. 1989. Effects of intense fishing pressure on an assemblage of coral reef fishes. Mar. Ecol. Prog. Ser. 56:13-27.

Samples, K. C., J. N. Kusakabe, and J. T. Sproul. 1984. A description and economic appraisal of charter fishing in Hawaii. Univ. Hawaii, Dep. Agric. and Resour. Econ., Admin. Rep. H-84-6C, 130 p.

Snepenger, D. J. and R. B. Ditton. 1985. A longitudinal analysis of nationwide hunting and fishing indicators: 1955-1980. Leisure Sci. 7:297-319.

Swanson, G. C., J. L. Seymour, and R. B. Ditton. 1978. An alternative perspective on common property resource allocation decisions in the coastal zone. Coast. Zone Manage. J. 4:25-45.

Taylor, K. H., F. J. Prochaska, and J. C. Cato. 1982. Economic returns in operating Florida Atlantic coast charter and party boats, 1980-1981. Fla. Sea Grant Coll. Program, Mar. Adv. Bull. MAP-28, 15 p.

USFWS. 1988. 1985 National survey of fishing, hunting, and wildlife associated recreation. U.S. Dep. Inter., Fish Wildl. Serv., Wash., D.C., 167 p.

————. 1989. 1985 National survey of fishing, hunting and wildlife-associated recreation: AL, FL, LA, MS, TX state reports. U.S. Dep. Inter., Fish Wildl. Serv., Wash., D.C. [Table 9, p. 18].

☆ U.S. GOVERNMENT PRINTING OFFICE: 1992—790-090/60004 REGION NO. 8

Superintendent of Documents **Subscriptions** Order Form

Order Processing Code:
* 5182

☐ **YES,** enter my subscription as follows:

Charge your order. It's Easy!

To fax your orders (202) 512–2233

____ subscriptions to **MARINE FISHERIES REVIEW (MRFM)** for $7.00 per year ($8.75 foreign).

The total cost of my order is $_________. Price includes regular domestic postage and handling and is subject to change.

(Company or Personal Name) (Please type or print)

(Additional address/attention line)

(Street address)

(City, State, ZIP Code)

(Daytime phone including area code)

(Purchase Order No.)

May we make your name/address available to other mailers? YES ☐ NO ☐

Please Choose Method of Payment:

☐ Check Payable to the Superintendent of Documents

☐ GPO Deposit Account ☐☐☐☐☐☐☐–☐

☐ VISA or MasterCard Account

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

☐☐☐☐ (Credit card expiration date)

Thank you for your order!

(Authorizing Signature) 12/91

Mail To: New Orders, Superintendent of Documents
P.O. Box 371954, Pittsburgh, PA 15250–7954

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
SCIENTIFIC PUBLICATIONS OFFICE
BIN C15700
SEATTLE, WA. 98115
OFFICIAL BUSINESS

Penalty for Private Use, $300

Second-Class Mail
Postage and Fees Paid
U.S. Department of Commerce
ISSN 0090-1830